Laboratory Manual

for

Instrumentation & Process Control

(3150504)

LUKHDHIRJI ENGINEERING COLLEGE, MORBI
MORBI

This is to certify that

Mr./Ms. ……………………………………………………………………………. Enrollment Number: ………………………….. Branch: Chemical, Semester: …….. Has satisfactorily completed the term work in the subject code..................and Name……………………………. from Lukhdhirji engineering college, Morbi.

Date of Submission: …………………… Staff in charge: ………….

Head of Department……………………………………………

LUKHDHIRJI ENGINEERING COLLEGE, MORBI

VISION

To provide quality engineering education and transforming students into professionally competent and socially responsible human beings.

MISSION

1. To provide a platform for basic and advanced engineering knowledge to meet global challenges.
2. To impart state-of-art know- how with managerial and technical skills.
3. To create a sustainable society through ethical and accountable engineering practices.

LUKHDHIRJI ENGINEERING COLLEGE, MORBI
CHEMICAL ENGINEERING DEPARTMENT

VISION

To develop professionally competent & socially responsible chemical engineers by providing quality education.

MISSION

1. To provide sound basic engineering knowledge to have a successful career in a professional environment.
2. To develop skill sets among the students to make them professionally competent.
3. To cater ethically strong engineers who shall be able to improve the quality of life and to work for sustainable development of society.

PEO's

PEO-1 To impart knowledge and skills in students to make them professionally competent in chemical process industries.

PEO-2 To motivate students for higher studies in technical and management fields.

PEO-3 To prepare students having soft skills along with leadership quality and management ability to make them successful entrepreneurs.

PEO-4 To implant the ethical principle and norms of engineering practices in terms of health, safety, and environmental context for the sustainable development of society.

PROGRAM OUTCOMES (POs)

Engineering Graduates will be able to:

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PSO

1) Apply the knowledge of chemical engineering to accomplish the contemporary need of chemical & Allied Industries.
2) To execute the chemical engineering principle and modern engineering tools to design system by considering safety, cost, health, legal, cultural and environmental aspects.

Chemical Engineering Department

Laboratory Safety Rules

1 Behave in a responsible manner at all times in the laboratory.
2 Ask your teacher before preceding any activity.
3 Keep silence.
4 Do not touch any equipment, chemicals, or other materials in the laboratory area until you are instructed to do so.
5 Perform only those experiments authorized by your teacher.
6 Do not eat food, drink beverages, or chew gum in the laboratory.
7 Always work in a well-ventilated area.
8 Work areas should be kept clean and tidy at all times.
9 Wash your hands after performing all experiments.
10 Dress properly during a laboratory activity. Long hair, dangling jewelry, and loose or baggy clothing are a hazard in the laboratory.
11 Never look into a container that is being heated.
12 Obey safety rules.
13 After Completion of Experiments turn off equipment properly.
14 Drain Water After Compilation of Experiments.
15 Before Living the Laboratory turns Off Light/Fan.

Undertaking of Ethics

1. I, hereby, promise to abide by the admissible rules and regulations, concerning discipline, attendance, etc. of the L.E.C.MORBI, and also to follow the Code of Conduct prescribed for the Students of the Institute, as in force from time to time and subsequent changes/modifications/amendment made thereto. I acknowledge that, the Institute has the authority for taking punitive actions against me for violation and/or non-compliance of the same.
2. I have performed all the experiments and their calculation done myself.

Signature of Student

Enrollment of Student

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2	Experiment	To find out the dynamics response of a first order system (liquid level) to a step changes in input variable						3150504.1 3150504.2	Interacting and Non interacting System
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FIRST ORDER DYANAMICS (THERMOMETER)

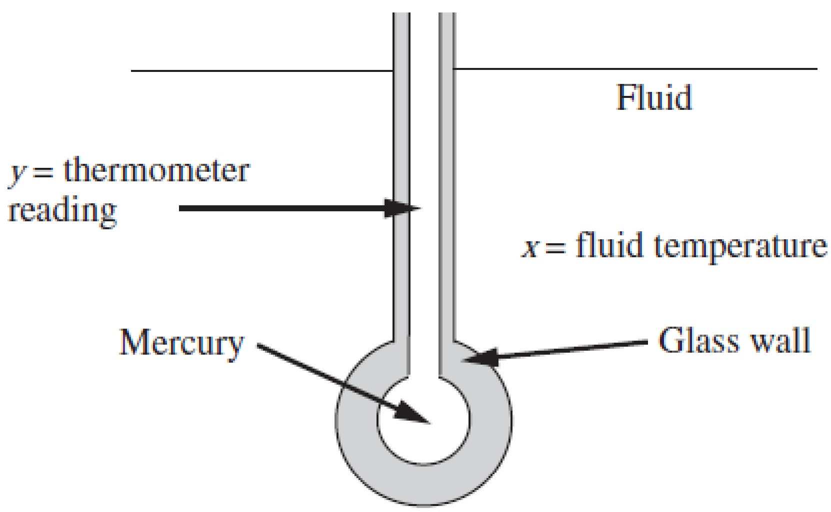
Aim: - To determine the time constant of a first order system (Thermometer) from its response to a step change in the Input Variable.

Apparatus:-

1. Mercury in glass thermometer of sufficiently large size bulb.
2. Water with a heater.
3. Stop watch.

Chemicals: - Water

Theory:



We shall develop the transfer the function for a first order system by considering the unsteady state behavior of ordinary mercury in glass thermometer. A cross sectional view of the bulb is shown in fig.

Consider the thermometer the to be located in a following stream of fluid for which the temperature X varies with time. Our problem is to calculate the response or time variation of the thermometer reading y for a particular change in X.

The following assumptions will be used in the analysis.

1. All the resistance to heat transfer resides in the film surrounding the bulb
2. All the thermal capacity is in the mercury. Furthermore, at any instant the mercury assumes a uniform temperature thought.

3. The glass wall containing the mercury does not expand or contract during the transient response.

It is assumed that the thermometer is initially at steady state. This means that, before time Zero, there is no change in temperature with time. At time Zero the thermometer will be subjected to some change in the surrounding temperature X (t)
By applying the unsteady state energy balance

Input rate – Output rate = rate of accumulation

We get the result

$hA\,(x-y)-\;0=mC\,\frac{dy}{dt}$…………………1.1

Where A = Surface area of bulb for heat transfer, ft^2

C = heat capacity of mercury, Btu/(lb_m)(˚F)

m= mass of mercury in bulb, lb_m

t = time, hr

h = film co-efficient of heat transfer, Btu/(hr) ft^2F

For the steady state condition above eq. may be written as

$hA\,(x-y_s)-\;0=mC\,\frac{dy_s}{dt}$ ....1.2 for = t<0

{$\frac{mCd(y_s)}{dt}=0$, because at steady state temperature not change with respect to time}

The subscript's' is used to indicate that the variable is the steady state value. Equation 1.2 simply that Ys = Xs, or the thermometer reads the true, bath temperature. Subtracting Equation 1.2 from Equation 1.1 gives

$hA\,[(x-\;x_s)-(y-\;y_s)]=mc\;\frac{d(y-\,y_s)}{dt}$……………………..1.3

Notice that $\frac{d(y-\,y_s)}{dt}=\frac{dy}{dt}$ because y_s is a constant.

If we define the deviation variables to be the difference between the variables and their steady state values

$X = x - x_s$

$Y = y - y_s$

Equation 1.3 becomes

$hA\,[(X)-(Y)]=mc\;\frac{d(Y)}{dt}$...1.4

If we let mc/ha= τ, Equation 1.4 becomes

X – Y = τ dY/dt...1.5

Taking Laplace Transform of Equation 1.5 gives

$X_{(s)}-Y_{(s)}=\tau sY_{(s)}$..1.6

Rearranging the equation 1.6 as a ratio of Y(s) to X(s) gives

Y(s)/ X(s) = 1/(τs + 1)..1.7

The parameter τ is called the time constant of the system and has the units of the time.

Any Physical system for which the relation between Laplace transform of input and output deviation variables if of the form given by eq.1.7 is called the first order system

Now we introduce step input in equation 1.7

$Y(S) = \left(\frac{1}{\tau_s + 1}\right)$X(s)…………1.8

X(s) = (1/s)………..because step input laplace transfrom form is (A/s)

$Y(S) = \left(\frac{1}{\tau_s + 1}\right)\frac{A}{s}$………..1.9

This can be expanded by partial fraction to give

$Y(s) = \frac{A/\tau}{s(\tau_s + 1)} = \frac{C_1}{s} + \frac{C_2}{\left(s + \frac{1}{\tau}\right)}$……..1.10

Solving for constants C_1 and C_2 by putting s = 0 and s = (-1/τ) we get C_1 = A and C_2 = -A

$Y(s) = \frac{A}{s} + \frac{-A}{\left(s + \frac{1}{\tau}\right)}$………1.11

We take inverse laplase

$Y(t) = A\left(1 - e^{\left(\frac{-t}{\tau}\right)}\right)$…….1.12

Procedure:

1. Take 250 ml of water in 500 ml beaker.
2. The beaker is kept on heater than water is heated with constant agitator by means of stirrer up to 90^{o}C.
3. Note down the room temperature.(It's initial steady state condition)
4. Dip the given thermometer in beaker and start the stop watch. Note down the temperature rise at every 5 sec interval up to particular temperature. (new steady state condition)
5. Now take out the thermometer from water bath start the stop watch and note down the temperature fall at every 5 second interval up to room temperature.

Observation:-

For positive step change:-
Initial temperature (Room temp.) = t_s = (ºC)
Final steady state temperature = t_f = (ºC)
Step input = A= t_f - t_s = (ºC)

Sr. No.	Time (sec)	Temp. indicated by thermometer (ºC) = t	T = t - t_s	T /A
1				
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For negative step change:-

Initial temperature = t_s = (°C)

Final steady state temperature = t_f = (°C)

Step input = A = $t_f - t_s$ = (°C)

Sr. No.	Time (sec)	Temp. indicated by thermometer(°C) = t	T = t – ts	T /A
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Calculation:
For positive step change
From Graph:

1. Time constant of thermometer from tangent to the response curve at time t = 0 sec τp1 =
2. Time constant of thermometer from 63.2% response its ultimate value τp2 =
3. Time constant of thermometer from analytical method τp3 =

$$\left(\frac{y(t)}{A}\right) = 1 - e^{-t/\tau p}$$

Find τp3

For negative step change
From Graph:

1. Time constant of thermometer from tangent to the response curve at time t = 0 sec τp1 =
2. Time constant of thermometer from 63.2% response its ultimate value τp2 =
3. Time constant of thermometer from analytical method τp3 =

$$\left(\frac{y(t)}{A}\right) = 1 - e^{-t/\tau p}$$

Find τp3

Graphs:

Draw the graph of T /A v/s time.

Results:

For Positive step change:

1. Time constant of thermometer from tangent to the response curve at time t = 0 sec τp1 =
2. Time constant of thermometer from 63.2% response its ultimate value τp2 =
3. Time constant of thermometer from analytical method τp3 =

For Negative step change:

1. Time constant of thermometer from tangent to the response curve at time t = 0 sec τp1 =
2. Time constant of thermometer from 63.2% response its ultimate value τp2 =
3. Time constant of thermometer from analytical method τp3 =

Conclusion:

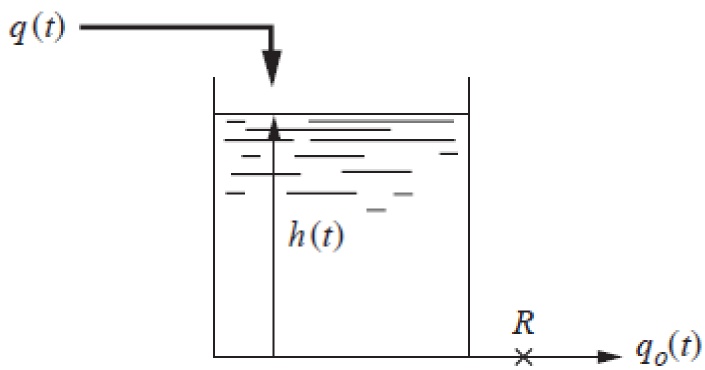
FIRST ORDER DYANAMICS (LIQUID LEVEL TANK)

Aim :- To find out the dynamics response of a first order system (liquid level) to a step changes in input variable.

Apparatus: - Interactive & Non-Interacting System Apparatus.

Chemicals: - Water

Theory:-



Consider unifrom cross sectional area A to which is attached a flow resistance R such as a valve, a pipe, or a weir. Assume that q_o, the volumetric flow rate (volume/time) through the resistance, is related to the head h by the linear relationship is $q_o = \frac{h}{R}$ ………(2.1)

A time varing volumetric flow q of liquid of constant density ρ enters the tank.
Determine the transfer function related head to flow
We are analysing this system by writing mass balance around the tank:
(Rate of mass flow in) – (Rate of mass flow out) = (Rate of accumulation of mass in tank)

$$\rho q(t) - \rho q_o(t) = \frac{d(\rho A h)}{dt}$$

$q(t) - q_o(t) = \frac{Ad(h)}{dt}$ (Because denstity is constant)……….(2.2)

Combining equation 2.1 and 2.2

$q - \frac{h}{R} = \frac{Ad(h)}{dt}$ ……………..(2.3)

We will introduce devation variable into analysis before proceeding to the transfer function. Initially, the process is operating at steady state, which means that $\frac{dh}{dt} = 0$ and we can write equation 2.3 as

$q_s - \frac{h_s}{R} = \frac{Ad(h_s)}{dt}$ $\{\frac{Ad(h_s)}{dt} = 0,$ because at steady state hight not change with respect to time}…2.4

Where the subscript s has been used to indicate the steady-state value of the variable.

Subtracting equation 2.4 from equation 2.3 gives,

$(q - q_s) - \left(\frac{(h - h_s)}{R}\right) = \frac{Ad(h - h_s)}{dt}$…………..2.5

If we defining deviation variable as

Q = $q - q_s$

H = $h - h_s$

Then equation 2.5 can be written as,

$Q - \left(\frac{H}{R}\right) = \frac{AdH}{dt}$…………2.6

Taking laplase transform of equation 2.6

$Q(s) - \frac{H(s)}{R} = A\big(sH(s) - H(0)\big)$ (initally H(0) = 0)

So,

$Q(s) - \frac{H(s)}{R} = A\big(sH(s)\big)$……………2.7

Slove above 2.7 equation

$\frac{RQ(s) - H(s)}{R} = A\big(sH(s)\big)$…….2.8

$RQ(s) - H(s) = RA\big(sH(s)\big)$…….2.9

$RQ(s) = H(s)\{RAs + 1\}$………2.10

$\frac{H(s)}{Q(s)} = \frac{R}{RA_s + 1}$……..2.11

Equation 2.11 comparing standard first order reaction

$\frac{H(s)}{Q(s)} = \frac{R}{\tau s + 1}$……..2.12

Were, $\tau = RA$

Now we introduce step input in equation 2.12

$H(S) = \left(\frac{R}{\tau_s + 1}\right)$Q(s)…………2.13

Q(s) = (A/s)………..because step input laplase transfrom form is (A/s)

$H(S) = \left(\frac{R}{\tau_s + 1}\right)\frac{A}{s}$………..2.14

This can be expanded by partial fraction to give

$H(s) = \frac{AR/\tau}{s(\tau_s + 1)} = \frac{C_1}{s} + \frac{C_2}{\left(s + \frac{1}{\tau}\right)}$……..2.15

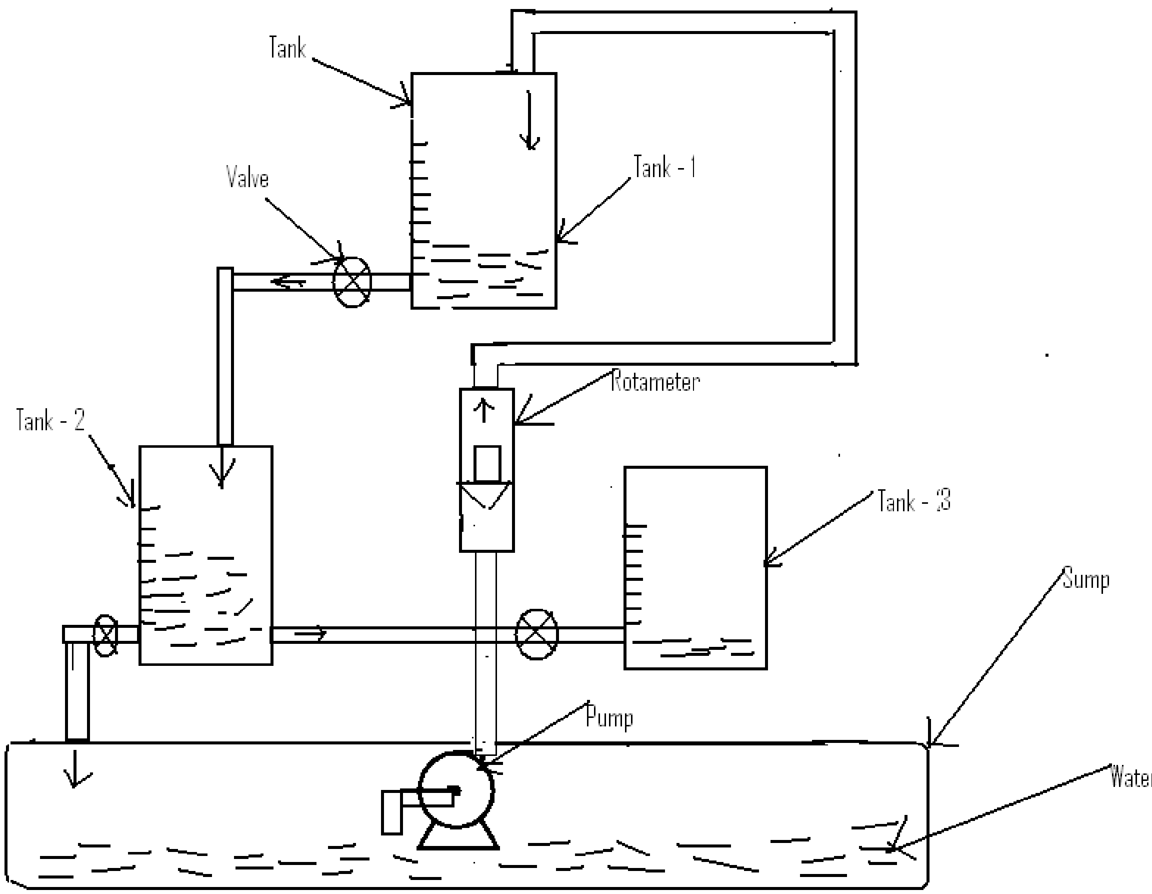
Solving for constants C_1 and C_2 by putting s = 0 and s = (-1/τ) we get C_1 = AR and C_2 = -AR

$H(s) = \frac{AR}{s} + \frac{-AR}{\left(s+\frac{1}{\tau}\right)}$………2.16

We take inverse laplase

$H(t) = AR\left(1 - e^{\left(\frac{-t}{\tau}\right)}\right)$…….2.17

Experimental Setup: LIQUID LEVEL TANK



Procedure:-

1. Start up set up.
2. A flexible pipe is provided at the rotameter outlet. Insert pipe in to the cover of the top Tank-1. Keep the outlet valves (R_1 & R_2) of the Tank-1& Tank-2 slightly closed.
3. Switch on pump. Adjust the initial flow rate & allow the system to steady state. Note down the height of the Tank-1(Initial steady state height=h_s)
4. Apply the step changes by increasing the rotameter flow by @20 lph.(positive step change.)
5. Immediately start recording the level of the Tank-1 at the interval of 10 sec, until the level reaches to new steady state condition.
6. Carry out the calculations as mention in calculation part & compare the predicted & observed values of the tank level.
7. Repeat the experiment for Negative step change. (Decreasing the rotameter flow by @ 20 lph.)

OBSERVATION:-

For step change:-

- Diameter of Tank-1 =
- Initial flow rate (LPM) =
- Final flow rate (LPM) =
- Initial steady state tank level(mm):
- Final steady state tank level(mm):

Observation Table:

Sr. No.	Time (sec)	Level of Tank-1(mm) (h)	H(t) observed = h - h_s	H(t) predicted
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Calculation:-

For Step Change

1. H(t) observed = (level at time t – level at time t=0)*10^{-3}m
2. H(t) predicted = AR $(1 – e^{-t/\tau})$ m

Where,

A = magnitude of step change

= (flow rate after step change – Initial flow rate) m^3 /sec

R = Outlet valve resistance in sec/m^2

dH = (final steady state level - Initial steady state level) m

dQ = (Flow rate after step change - Initial flow rate) m^3 /sec

τ = time constant in sec = A_1* R

Where,

A_1 = Area of tank in m^2 =

t = time in sec

For step change

$A = Q_2 – Q_1$

=

= ---------- m^3/sec

R = dH/dQ

=

= -------------

Here,

$A_1 = \pi/4 * (d)^2$

=

= m^2

$\tau = A_1 * R$

=

=

Here,

H(t) predicted = $AR(1 – e^{-t/\tau})$

=

=

Graph:-

Draw the graph of H(t) observed Vs time and H(t) predicted Vs time

Results:-

τ in Sec	Total Time in Sec	Final H(t) observed	Final H(t) predicted

Conclusion:-

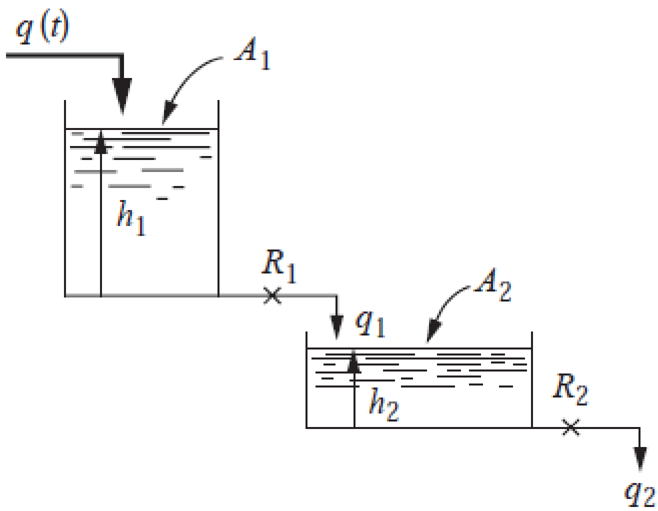
NON –INTERACTING SYSTEM (STEP INPUT)

Aim: To find out the dynamics response of a first order system (Liquid level tank arranged in non-interacting mode) to a step change in input variable.

Apparatus: Interacting and Non-Interacting System Apparatus

Chemical: Water

Theory:



A balance for tank 1

Consider cross sectional area for tank 1 is A1 to which is attached a flow resistance for tank 1 is R1 such as a valve, a pipe, or a weir. Assume that q_1, the volumetric flow rate (volume/time) through the resistance, is related to the head h by the linear relationship is $q_1 = \frac{h_1}{R_1}$ 3.1

A time varing volumetric flow q of liquid of constant density ρ enters the tank.
Determine the transfer function related head to flow
We are analysing this system by writing mass balance around the tank 1:
(Rate of mass flow in) – (Rate of mass flow out) = (Rate of accumulation of mass in tank)

$$\rho q(t) - \rho q_1(t) = \frac{d(\rho A_1 h)}{dt}$$

$$q(t) - q_1(t) = \frac{A_1 d(h_1)}{dt}$$ (Because denstity is constant)……….3.2

Combining equation 3.1 and 3.2

$q - \frac{h_1}{R_1} = \frac{A_1 d(h_1)}{dt}$ ……………..3.3

We will introduce devation variable into analysis before proceeding to the transfer function. Initially, the process is operating at steady state, which means that $\frac{dh_1}{dt} = 0$ and we can write equation 3.3 as

$q_s - \frac{h_{1s}}{R_1} = \frac{A_1 d(h_{1s})}{dt}$ { $\frac{A_1 d(h_{1s})}{dt} = 0$, because at steady state hight not change with respect to time}…3.4

Where the subscript s has been used to indicate the steady-state value of the variable.

Subtracting equation 3.4 from equation 3.3 gives,

$(q - q_s) - \left(\frac{h_1 - h_{1s}}{R_1}\right) = \frac{A_1 d(h_1 - h_{1s})}{dt}$…………..3.5

If we defining deviation variable as

Q = $q - q_s$

$H_1 = h_1 - h_{1s}$

Then equation 3.5 can be written as,

$Q - \left(\frac{H_1}{R_1}\right) = \frac{A_1 dH_1}{dt}$…………3.6

Taking laplase transform of equation 3.6

$Q(s) - \frac{H_1(S)}{R_1} = A_1\big(sH_1(s) - H_1(0)\big)$ (initally $H_1(0) = 0$)

So,

$Q(s) - \frac{H_1(S)}{R_1} = A_1\big(sH_1(s)\big)$……………3.7

Slove above 3.7 equation

$\frac{R_1 Q(s) - H_1(s)}{R_1} = A_1\big(sH_1(s)\big)$…….3.8

$R_1 Q(s) - H_1(s) = R_1 A_1\big(sH_1(s)\big)$…….3.9

$R_1 Q(s) = H_1(s)\{R_1 A_1 s + 1\}$………3.10

$\frac{H_1(s)}{Q(s)} = \frac{R_1}{R_1 A_1 s + 1}$……..3.11

Equation 3.11 comparing standard first order reaction

$\frac{H_1(s)}{Q(s)} = \frac{R_1}{\tau_1 s + 1}$……..3.12

Were, $\tau_1 = R_1 A_1$

A balance for tank 2

Consider cross sectional area for tank 2 is A2 to which is attached a flow resistance for tank 2 is R2 such as a valve, a pipe, or a weir. Assume that q_2, the volumetric flow rate (volume/time) through the resistance, is related to the head h by the linear relationship is $q_2 = \frac{h_2}{R_2}$ ………3.13

A time varing volumetric flow q of liquid of constant density ρ enters the tank. Determine the transfer function related head to flow

We are analysing this system by writing mass balance around the tank 2.

(Rate of mass flow in) – (Rate of mass flow out) = (Rate of accumulation of mass in tank)

$\rho q_1(t) - \rho q_2(t) = \frac{d(\rho A_2 h_2)}{dt}$

$q_1(t) - q_2(t) = \frac{A_2 d(h_2)}{dt}$ (Because denstity is constant)……….3.14

Combining equation 3.13 and 3.14

$\frac{h_1}{R_1} - \frac{h_2}{R_2} = \frac{A_2 d(h_2)}{dt}$ ……………..3.15

We will introduce devation variable into analysis before proceeding to the transfer function. Initially, the process is operating at steady state, which means that $\frac{dh_2}{dt} = 0$ and we can write equation 3.15 as

$\frac{h_{1s}}{R_1} - \frac{h_{2s}}{R_2} = \frac{A_2 d(h_{2s})}{dt}$ { $\frac{A_2 d(h_{2s})}{dt} = 0$, because at steady state hight not change with respect to time}…3.16

Where the subscript s has been used to indicate the steady-state value of the variable.

Subtracting equation 3.16 from equation 3.12 gives,

$\left(\frac{h_1 - h_{1s}}{R_1}\right) - \left(\frac{h_1 - h_{1s}}{R_1}\right) = \frac{A_2 d(h_2 - h_{2s})}{dt}$…………..3.17

If we defining deviation variable as

$H_1 = h_1 - h_{1s}$

$H_2 = h_2 - h_{2s}$

Then equation 3.17 can be written as,

$\left(\frac{H_1}{R_1}\right) - \left(\frac{H_2}{R_2}\right) = \frac{A_2 dH_2}{dt}$…………3.18

Taking laplase transform of equation 3.18

$\frac{H_1(S)}{R_1} - \frac{H_2(S)}{R_2} = A_2\left(sH_2(s) - H_2(0)\right)$ (initally $H_2(0) = 0$)

So,

$\frac{H_1(S)}{R_1} - \frac{H_2(S)}{R_2} = A_2\left(sH_2(s)\right)$……………3.19

Slove above 3.19 equation

$\frac{R_2 H_1(s) - R_1 H_2(s)}{R_1 R_2} = A_2\left(sH_2(s)\right)$…….3.20

$R_2 H_1(s) - R_1 H_2(s) = R_1 R_2 A_2\left(sH_2(s)\right)$…….3.21

$R_2 H_1(s) = H_2(s)\{R_1 R_2 A_2 s + R_1\}$………3.22

$\frac{H_2(s)}{H_1(s)} = \frac{R_2}{R_1 R_2 A_2 s + R_1}$……..3.23

Equation 3.23 comparing standard first order reaction

$\frac{H_2(s)}{H_1(s)} = \frac{R_2}{R_1(\tau_2 s + 1)}$……..3.24

Were, $\tau_2 = R_2 A_2$

Now, finally multiplay equation 3.12 and 3.24

$\frac{H_1(s)}{Q(s)} * \frac{H_2(s)}{H_1(s)} = \frac{R_1}{\tau_1 s+1} * \frac{R_2}{R_1(\tau_2 s+1)}$……………….3.25

Finally we get,

$\frac{H_2(s)}{Q(s)} = \frac{R_2}{(\tau_2 s+1)(\tau_1 s+1)}$ ……….3.26

Now we introduce step input in equation 3.27

$H_2(s) = \frac{R_2}{(\tau_2 s+1)(\tau_1 s+1)}$Q(s)…………3.28

Q(s) = (A/s)………..because step input laplase transfrom form is (A/s)

$H_2(s) = \frac{R_2}{(\tau_2 s+1)(\tau_1 s+1)}\frac{A}{s}$………..3.29

This can be expanded by partial fraction to give

$H_2(s) = \frac{AR_2/\tau_1\tau_2}{S(\tau_2 s+1)(\tau_1 s+1)} = \frac{C_1}{s} + \frac{C_2}{\left(s+\frac{1}{\tau_1}\right)} + \frac{C_3}{\left(s+\frac{1}{\tau_2}\right)}$…………3.30

Solving for constants C_1 , C_2 and C_3 by putting s = 0 , s = ($-1/\tau_1$) and s = ($-1/\tau_2$) we get $C_1 = AR_2$, $C_2 = (AR_2\tau_1)/(\tau_2 - \tau_1)$ and $C_3 = (AR_2\tau_2)/(\tau_2 - \tau_1)$

$H_2(s) = \frac{AR_2}{s} - \frac{(AR_2\tau_1)/(\tau_1-\tau_2)}{\left(s+\frac{1}{\tau_1}\right)} - \frac{(AR_2\tau_2)/(\tau_1-\tau_2)}{\left(s+\frac{1}{\tau_2}\right)}$………………3.31

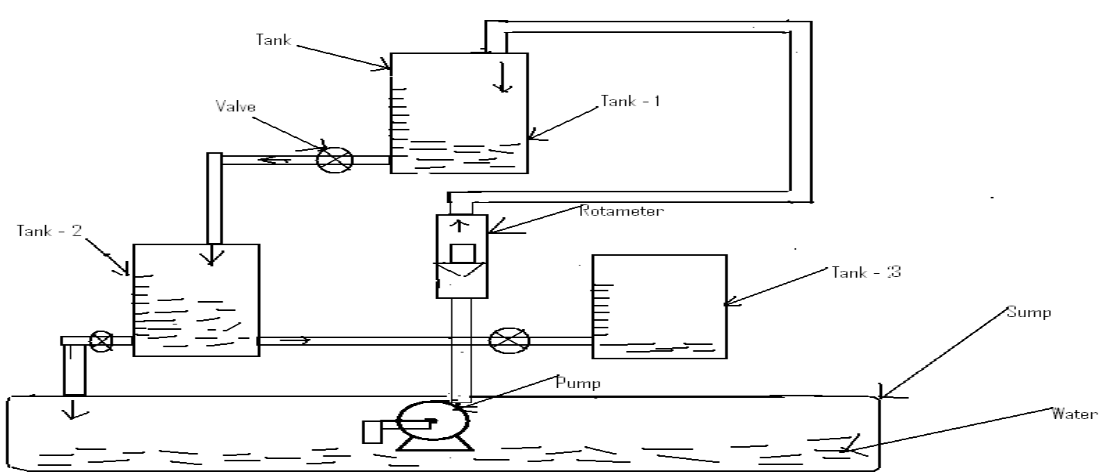
$H_2(s) = AR_2\left(\frac{1}{s} - \frac{(\tau_1)/(\tau_1-\tau_2)}{\left(s+\frac{1}{\tau_1}\right)} - \frac{(\tau_2)/(\tau_1-\tau_2)}{\left(s+\frac{1}{\tau_2}\right)}\right)$………………3.32

$H_2(s) = AR_2\left(\frac{1}{s} - \frac{(\tau_1)/(\tau_1-\tau_2)}{\left(s+\frac{1}{\tau_1}\right)} - \frac{(\tau_2)/(\tau_2-\tau_1)}{\left(s+\frac{1}{\tau_2}\right)}\right)$………………3.33

We take inverse laplase

$H_2(t) = AR_2\left(1 - \frac{1}{(\tau_1-\tau_2)}\left(\tau_1 e^{\left(\frac{-t}{\tau_1}\right)} - \tau_2 e^{\left(\frac{-t}{\tau_2}\right)}\right)\right)$…….3.34

Experimental Setup: LIQUID LEVEL (NON INTERACTING SYSTEM)



Procedure:

1. Start up the set up.
2. A flexible pipe is provided at the rotameter outlet. Insert the pipe into the cover of the top tank-1.Keep the outlet valves (R_1 & R_2) of the tank-1 and tank-2 slightly closed.
3. Switch on the pump. Adjust the initial flow rate and allow the level of both tanks (tank-1 & tank-2) to reach steady state. Note down the height of the tank1 & tank-2 (initial steady state height = h_s)
4. Apply the step change by increasing the rotameter flow by @20 lph (positive step change)
5. Immediately start recording the level of the tank-2 at the interval of 10 sec, until level reaches to the new steady state condition.
6. Note down the final flow and steady state level of tank-1.
7. Carry out the calculation as mentioned in calculation part and compare the predicated and observed value of the tank-2 level.

Observation:

For Step change

Area of tank-1& tank-2 :
Initial flow rate (LPM) :
Final flow rate (LPM) :
Initial steady state tank level tank-1(mm) :
Final steady state tank level tank-1 (mm) :
Initial steady state tank level tank-2(mm) :
Final steady state tank level tank-2 (mm) :

Observation Table:

Sr No.	Time (sec)	Tank-2 h2 (mm)	H2(t)=h2-hs2	H2(t) Predicted
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
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28				
29				
30				

Calculations:

H(t) Observed = (level at time t – level at time t=0) X 10^{-3}
H(t) Predicated = $AR_2\{1-\{(\tau_1 \times \tau_2)/(\tau_1 - \tau_2)\}\{(e^{-t/\tau_1}/\tau_2) - (e^{-t/\tau_2}/\tau_1)\}\}$m

Where,
A = magnitude step change
= (flow rate after step change – Initial flow rate) m^3/sec
R = Outlet valve resistance in sec/m^2
dH_1 = (final steady state level – Initial steady state level) for tank-1 m
dH_2 = (final steady state level – Initial steady state level) for tank-2 m
dQ = (flow rate after step change – initial flow rate) m^3/sec

τ = time constant in sec
$\tau_1 = A_1 \times R_1$
$\tau_2 = A_2 \times R_2$
Where $A_1 = A_2$ = Area of tank 1 & tank-2 in m^2

$A_1 = A_2 = (\pi/4) \times d^2$
=
=

$R_1 = dH_1/dQ$
=
=

$R_2 = dH_2/dQ$
=
=

$\tau_1 = A_1 \times R_1$
=

τ_1 =

$\tau_2 = A_2 \times R_2$

=

τ_2 =

$H_2(t)$ Predicated

$$H_2(t) = AR_2\left(1 - \frac{1}{(\tau_1 - \tau_2)}\left(\tau_1 e^{\left(\frac{-t}{\tau_1}\right)} - \tau_2 e^{\left(\frac{-t}{\tau_2}\right)}\right)\right)$$

Graphs:

Draw the graph of $H_2(t)$ observed Vs time and H_2 (t) predicted Vs time

Results:

τ_1 in Sec	τ_2 in Sec	Total Time in Sec	Final H_2 (t) observed	Final H_2 (t) predicted

Conclusion:

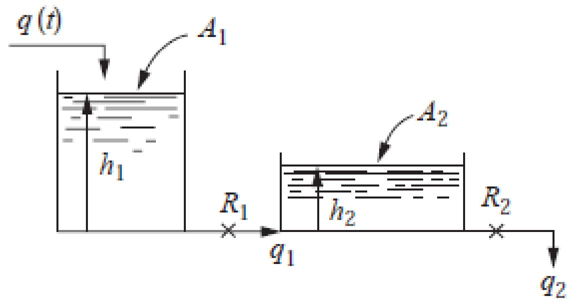
INTERACTING SYSTEM (STEP INPUT)

Aim: To find out the dynamics response of a first order system (Liquid level tank arranged in interacting mode) to a step change in input variable.

Apparatus: Interacting and Non-Interacting System Apparatus

Chemical: Water

Theory:



To, illustrate interacting system, we will derive the transfer function for the system in figure, the analysis is started by writing mass balance on the tank as we done for non interacting case, the balance on tank 1 and tank 2 are the same as before and are given in non interacting tank.

$q - q_1 = A_1 * \frac{dh_1}{dt}$……….4.1

$q_1 - q_2 = A_2 * \frac{dh_2}{dt}$……….4.2

However, the flow head relationship for R_1 is now,

$q_1 = \frac{1}{R_1}(h_1 - h_2)$……….4.3

The flow head relationship for R_2 is now,

$q_1 = \frac{h_2}{R_2}$ ……….4.4

We introducing deviation variable in to analysis before proceeding to the transfer function.

Initially the process is operating steady state, which means that $\frac{dh_1}{dt} = 0$ and $\frac{dh_2}{dt} = 0$ and we can write equation 4.1 and 4.2 as

$q_s - q_{1s} = A_1 * \frac{dh_{1s}}{dt}$………4.5

$q_{1s} - q_{2s} = A_2 * \frac{dh_{2s}}{dt}$………4.6

$\frac{dh_{1s}}{dt} = 0$ and $\frac{dh_{2s}}{dt} = 0$, because steady state height is not change with time.

Where the subscript s has been used to indicate the steady state value of variable.

Now, equation 4.1 – 4.5 and 4.2 – 4.6

$(q - q_s) - (q_1 - q_{1s}) = \frac{A_1 d(h_1 - h_{1s})}{dt}$……….4.7

$(q_1 - q_{1s}) - (q_2 - q_{2s}) = \frac{A_2 d(h_2 - h_{2s})}{dt}$…………4.8

$q - q_s = Q, q_1 - q_{1s} = Q_1, h_1 - h_{1s} = H_1, h_2 - h_{2s} = H_2, q_2 - q_{2s} = Q_2$

$Q - Q_1 = \frac{A_1\, dH_1}{dt}$…………4.9

$Q_1 - Q_2 = \frac{A_2\, dH_2}{dt}$…………4.10

$Q_1 = \frac{H_1 - H_2}{R_1}$…………4.11

$Q_2 = \frac{H_2}{R_2}$………..4.12

Taking laplase of equation 4.9, 4.10, 4.11 and 4.12

$Q(s) - Q_1(s) = A_1\big(SH_1(s) - H_1(0)\big)$……….4.13

$Q_1(s) - Q_2(s) = A_2\big(SH_2(s) - H_2(0)\big)$……….4.14

$R_1Q_1(s) = H_1(s) - H_2(s)$……..4.15

$R_2Q_2(s) = H_2(s)$………..4.16

Initially $H_1(0) = 0$ and $H_2(0) = 0$ so,

$Q(s) - Q_1(s) = A_1\big(SH_1(s)\big)$……….4.17

$Q_1(s) - Q_2(s) = A_2\big(SH_2(s)\big)$……….4.18

$R_1Q_1(s) = H_1(s) - H_2(s)$……..4.19

$R_2Q_2(s) = H_2(s)$………..4.20

Equation 4.17 plus 4.18

$Q(s) - Q_1(s) = A_1\big(SH_1(s)\big)$.

$Q_1(s) - Q_2(s) = A_2\big(SH_2(s)\big)$.

$Q(s) - Q_2(s) = A_1\big(SH_1(s)\big) + A_2\big(SH_2(s)\big)$.

Putting $Q_2(s) = \frac{H_2(s)}{R_2}$

$Q(s) - \frac{H_2(s)}{R_2} = A_1\big(SH_1(s)\big) + A_2\big(SH_2(s)\big)$.

$R_2Q(s) - H_2(s) = R_2A_1\big(SH_1(s)\big) + R_2A_2\big(SH_2(s)\big)$.

$R_2Q(s) = R_2A_1\big(SH_1(s)\big) + R_2A_2\big(SH_2(s)\big) + H_2(s)$…………4.21

Value of Q_1 and Q_2 from equation 4.11 and 4.12 and put in equation 4.18

$\frac{H_1(s) - H_2(s)}{R_1} - \frac{H_2(s)}{R_2} = A_2SH_2(s)$.

$R_2(H_1(s) - H_2(s)) - R_1\big(H_2(s)\big) = R_1R_2A_2SH_2(s)$.

$R_2H_1(s) - R_2H_2(s) - R_1(H_2(s)) = R_1R_2A_2SH_2(s).$

$R_2H_1(s) = R_1R_2A_2SH_2(s) + R_2H_2(s) + R_1(H_2(s))$.

$R_2H_1(s) = H_2(s)(R_1R_2A_2S + R_2 + R_1).$

$R_2H_1(s) = H_2(s)(R_1\tau_2s + R_2 + R_1)$…………4.22 (Because$R_2A_2 = \tau_2$)

From equation 4.22 $R_2H_1(s)$ value in equation 4.22

$R_2Q(s) = [A_1sH_2(s)(R_1\tau_2s + R_2 + R_1) + \tau_2(SH_2(s)) + H_2(s)].$

$R_2Q(s) = H_2(s)[A_1s(R_1\tau_2s + R_2 + R_1) + \tau_2S + 1].$

$R_2Q(s) = H_2(s)[A_1R_1\tau_2s^2 + A_1R_2s + A_1R_1s + \tau_2S + 1].$

$R_2Q(s) = H_2(s)[\tau_1\tau_2s^2 + A_1R_2s + \tau_1s + \tau_2S + 1]$. (Because$R_1A_1 = \tau_1$)

$R_2Q(s) = H_2(s)[\tau_1\tau_2s^2 + (A_1R_2 + \tau_1 + \tau_2)s + 1].$

$\frac{H_2(s)}{Q(s)} = \frac{R_2}{[\tau_1\tau_2s^2+(A_1R_2+\tau_1+\tau_2)s+1]}$…………..4.23

Assume $A_1 = A_2$

So,

$\frac{H_2(s)}{Q(s)} = \frac{R_2}{[\tau_1\tau_2s^2+(\tau_2+\tau_1+\tau_2)s+1]}$……..4.24

Now, we introduce step input in equation 4.24

$H_2(s) = \frac{R_2}{[\tau_1\tau_2s^2+(\tau_2+\tau_1+\tau_2)s+1]} Q(s)$ …………4.25

$Q(s) = \left(\frac{A}{s}\right)$……….because step input laplase transform from is $\left(\frac{A}{s}\right)$

This can be expanded by partial fraction to give

$H_2(s) = \frac{AR_2}{s[\tau_1\tau_2s^2+(\tau_2+\tau_1+\tau_2)s+1]}.$

To understand the effect of interaction on the response of a system considers a two tank system. For which the time constant are equal ($\tau_1 = \tau_2 = \tau$) if the tanks are non-interacting the transfer function is known by

$Q_2(s)/Q(s) = (1/(\tau s+1))^2$

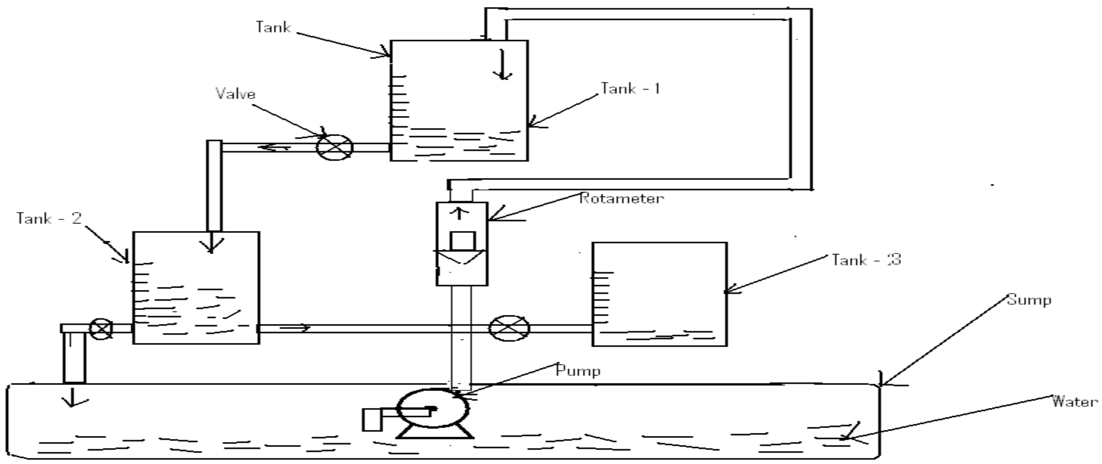
Unit step response transfer function is given by

$Q_2 = 1 - e^{-t/\tau} - (t/\tau)\, e^{-t/\tau}$

For interacting tanks over all transfer function is

$Q_2(s)/Q(s) = 1/(\tau^2S^2 + 3\tau S + 1)$

Experimental Setup: LIQUID LEVEL (INTERACTING SYSTEM)



Procedure:

1. Start up the set up.
2. A flexible pipe is provided at the rotameter outlet. Insert the pipe into the cover of the top Tank-3. Keep the outlet valves (R3 & R2) of the tank3 and tank2 slightly closed.
3. switch on the pump.Adjust the initial flow rate and allow the level of both tanks (tank-3 & tank-2) to reach steady state . Note down the height of the tank3 & tank-2 (initial stady state height = h_s)
4. Apply the step change by increasing the rotameter flow by @10Lph (Positive step change)
5. Immediately start recording the level of the tank-2 at the interval of 10Sec,Until level reaches to the new steady state condition.
6. Note down the final flow and steady state level of tank-3.
7. Carry out the calculation as mentioned in calculation part and compare the predicated and observed value of the lank-2 level.
8. Repeat the experiment for negative step change. (Decreasing the rotameter flow by @10 Lph)

Observation:

For Step change

Area of tank-2 & tank-3 :
Initial flow rate (LPM) :
Final flow rate (LPM) :
Initial steady state tank level tank-2(mm) :
Final steady state tank level tank-2(mm) :
Initial steady state tank level tank-3(mm) :
Final steady state tank level tank-3 (mm) :

Observation Table:

Sr No.	Time (sec)	Tank-3 h2 (mm)	H2(t)=h2-hs2	H2(t) Predicted
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
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19				
20				
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22				

23				
24				
25				
26				
27				
28				
29				
30				

Calculations:

H(t) Observed = (level at time t – level at time t=0) X 10^{-3}
H(t) Predicated = $AR_2\{1-\{(\tau_1 \times \tau_2)/ (\tau_1 - \tau_2)\}\{(e^{-t/\tau_1}/\tau_2) - (e^{-t/\tau_2}/\tau_1)\}\}$m

Where,
A = magnitude step change
= (flow rate after step change – Initial flow rate) m^3/sec
R = Outlet valve resistance in sec/m^2
dH_1 = (final steady state level – Initial steady state level) for tank-1 m
dH_2 = (final steady state level – Initial steady state level) for tank-2 m
dQ = (flow rate after step change – initial flow rate) m^3/sec

τ = time constant in sec
$\tau_1 = A_1 \times R_1$
$\tau_2 = A_2 \times R_2$

Where $A_1 = A_2$ = Area of tank 1 & tank-2 in m^2

$A_1 = A_2 = (\pi/4) \times d^2$
=
=

$R_1 = dH_1/dQ$
=
=

$R_2 = dH_2/dQ$
=

=

$\tau_1 = A_1 X R_1$

=

τ_1 =

$\tau_2 = A_2 X R_2$

=

τ_2 =

$b = \{1/\tau_1 + 1/ \tau_2 + (A_1 X R_2/ \tau_1 \tau_2)\}$

$\boldsymbol{\alpha} = (-b/2) + \{(b/2)^2 - (1/ \tau_1 \tau_2)\}^{1/2}$

$\boldsymbol{\beta} = (-b/2) - \{(b/2)^2 - (1/ \tau_1 \tau_2)\}^{1/2}$

H(t) Predicated

$AR_2 \{1 - \{(e^{\alpha t}/\alpha - e^{\beta t}/\beta)/ (1/\alpha - 1/\beta)\}\}$

Graphs:

Draw the graph of $H_2(t)$ observed Vs time and H_2 (t) predicted Vs time

Results:

τ_1 in Sec	τ_2 in Sec	Total Time in Sec	Final H_2 (t) observed	Final H_2 (t) predicted

Conclusion:

SECOND ORDER UNDERDAMED SYSTEM (MANOMETER)

Aim: To study the dynamic response of a second order under damped system to a step change in input variable.

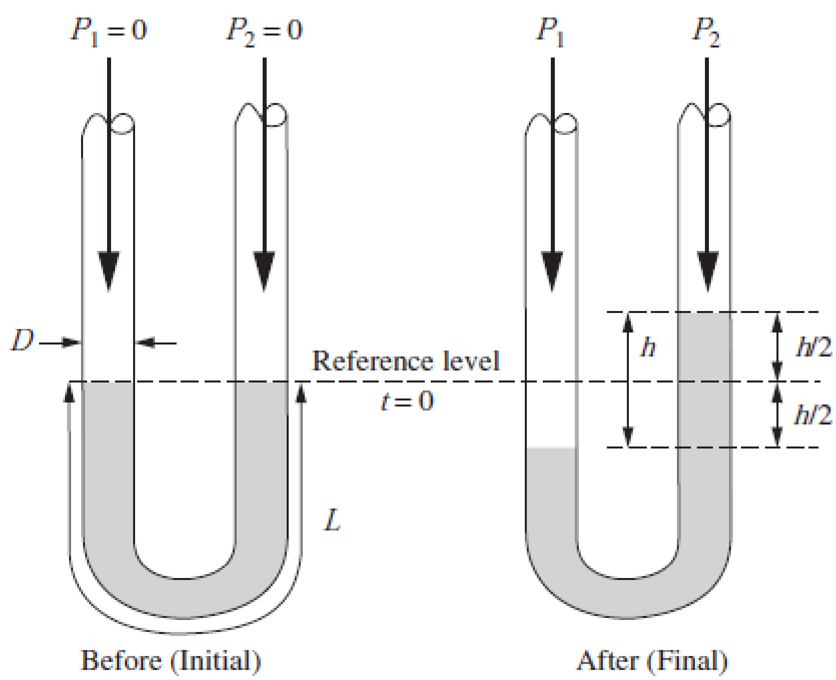
Apparatus: A U-tube manometer of sufficient inside diameter, filled with the mercury
A compressed air supplier
Stop watch

Chemical: Mercury

Theory:

Consider a simple manometer as shown in Fig. The pressure on both legs of the manometer is initially the same. The length of the fluid column in the manometer is L. At time t = 0, a pressure difference is imposed across the legs of the manometer. Assuming the resulting flow in the manometer to be laminar and the steady-state friction law for drag force in laminar flow to apply at each instant, we will determine the transfer function between the applied pressure difference P and the manometer reading h. If we perform a momentum balance on the fluid in the manometer, we arrive at the following terms

(Sum of forces causing fluid to move) - (R ate of change of momentum of fluid)……..5.1



Where,

(Sum of forces causing fluid to move) = (Unbalanced Pressure forces causing motion) – (Frictional forces opposing motion)

(Unbalanced Pressure forces causing motion) = $(P_1 - P_2) * \left(\frac{\pi}{4}\right) D^2 - (\rho g h) * \left(\frac{\pi}{4}\right) D^2$………5.2

(Frictional forces opposing motion) = (Skin friction at wall) = (Shear stress at wall) * (Area in contact with wall)

(Frictional forces opposing motion) =
$(\tau_{wall}) * (\pi D L) = (8\mu V|D) * (\pi D L) = (8\mu|D) * (1dh|2dt) * (\pi D L)$…………5.3

The term for the skin friction at the wall is obtained from the Hagen-Poiseuille relationship for laminar flow (McCabe, Smith and Harriott, 2004). Note that V is the average velocity of the fluid in the tube, which is also the velocity of the interface, which is equal to $(1dh|2dt)$ (See below figure)

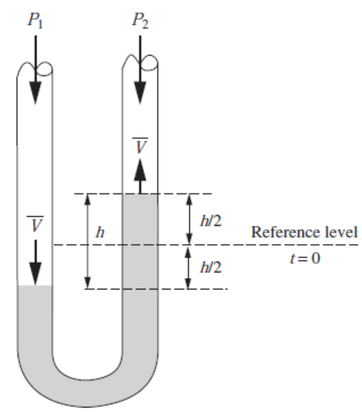


Fig. Average velocity of the fluid in the manometer.

The rate of change of momentum of the fluid [the right side of Eq. (5.1)] may be expressed as

(Rate of change of momentum) = $\frac{d}{dt}(mass * velocity * momentum\ correction\ factor)$

$$= \left(\rho * \left(\frac{\pi D^2 L}{4}\right)\right) * \beta * \frac{dV}{dt} \text{……5.4}$$

$$= \left(\rho * \left(\frac{\pi D^2 L}{4}\right)\right) * \beta * (1d^2h \,|\, 2dt^2) \text{……5.5}$$

The momentum correction factor b accounts for the fact that the fluid has a parabolic velocity profile in the tube, and the momentum must be expressed as b m V for laminar flow (see McCabe, Smith and Harriott, 2004). The value of b for laminar flow is 4/3. Substituting the appropriate terms into Eq. (5.2) produces the desired force balance equation for the manometer.

$\left(\rho * \left(\frac{\pi D^2 L}{4}\right)\right) * \left(\frac{4}{3}\right) * (1d^2h|2dt^2) = (P_1 - P_2) * \left(\frac{\pi}{4}\right)D^2 - (\rho gh) * \left(\frac{\pi}{4}\right)D^2 - (8\mu|D) *$
$(1dh|2dt) * (\pi DL)$…..5.6

Rearranging Eq. (5.6), we obtain

$\left(\rho * \left(\frac{\pi D^2 L}{4}\right)\right) * \left(\frac{4}{3}\right) * (1d^2h|2dt^2) + (8\mu|D) * (1dh|2dt) * (\pi DL) + (\rho gh) * \left(\frac{\pi}{4}\right)D^2 =$
$(P_1 - P_2) * \left(\frac{\pi}{4}\right)D^2$…….5.7

So, dividing both sides by$(\rho g) * \left(\frac{\pi}{4}\right)D^2$, we arrive at the standard form for a second-order system.

$(2Ld^2h|3gdt^2) + (16\mu L|\rho D^2 g) * (dh|dt) + h = \frac{P_1 - P_2}{\rho g} = \frac{\Delta P}{\rho g}$…………….5.8

A more detailed version of the analysis of the manometer can be found in Bird et al.,1960). Note that as with first-order systems, standard form has a coefficient of 1 on the dependent variable term, h in this case. Second-order systems are described by a second order differential equation. We may rewrite this Eq. (5.8) in general terms as

$\tau^2 \frac{d^2y}{dt^2} + 2\xi\tau\frac{dy}{dt} + Y = X(t)$………5.9

Where,

$\tau^2 = \frac{2L}{3g}$…..5.10

$2\xi\tau = (16\mu L|\rho D^2 g)$…...5.11

$Y = h \; and \; X(t) = \frac{\Delta P}{\rho g}$………5.12

Solving for τ and ξ from Eqs. (5.10) and (5.11) gives

$\tau = \sqrt{\frac{2L}{3g}}$ S …………………….5.13

$\xi = (8\mu|\rho D^2) * \sqrt{\frac{3L}{2g}}$ Dimensionless …………5.14

By definition, both t and z must be positive. The reason for introducing τ and ξ in the particular form shown in Eq. (5.9) will become clear when we discuss the solution of Eq. (5.9) for particular forcing functions X (t).

Equation (5.9) is written in a standard form that is widely used in control theory. If the fluid column is motionless (dY / dt = 0) and located at its rest position (Y = 0) before the forcing function is applied, the Laplace transform of Eq. (5.8) becomes

$\tau^2 s^2 Y(s) + 2\xi\tau sY(s) + Y(s) = X(s)$……..5.15

From this, the transfer function follows:

$\frac{Y(s)}{X(s)} = \frac{1}{\tau^2 s^2 + 2\xi\tau s + 1}$……….5.16

The transfer function given by Eq. (5.16) is written in standard form, and we will show later that other physical systems can be represented by a transfer function having the denominator of $\tau^2 s^2 + 2\xi\tau s + 1$. All such systems are defined as second-order. Note that it requires two parameters, τ and ξ, to characterize the dynamics of a second-order system in contrast to only one parameter for a first-order system. We now discuss the response of a second-order system to some of the common forcing functions, namely, step, impulse, and sinusoidal.

Step Response

If the forcing function is a unit-step function, we have

$X(S) = \frac{1}{S}$……..5.17

In terms of the manometer shown in Fig, this is equivalent to suddenly applying a pressure difference [such that$X(t) = \frac{\Delta P}{\rho g} = 1$] across the legs of the manometer at time t = 0.

Superposition will enable us to determine easily the response to a step function of any other magnitude.

Combining Eq. (5.17) with the transfer function of Eq. (5.16) gives

Y(s)= $\frac{1}{S}\frac{1}{\tau^2 s^2 + 2\xi\tau s + 1}$………5.18

Inverse laplase we get for underdamped system

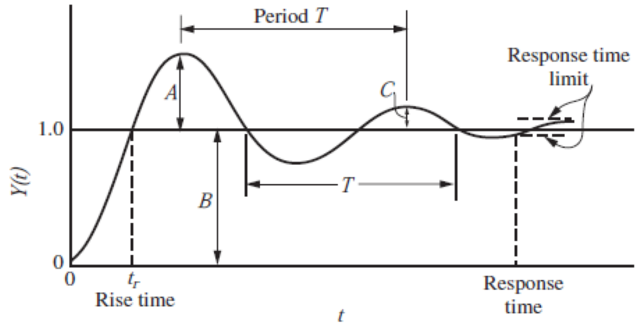
Y (t)= $1 - \frac{1}{\sqrt{1-\xi^2}} e^{\left(-\xi t/\tau\right)} * sin\left[\left(\sqrt{1-\xi^2} * \frac{t}{\tau}\right) + \left(tan^{-1}\frac{\sqrt{1-\xi^2}}{\xi}\right)\right]$……….5.19

Terms Used to Describe an Underdamped System

Of these three cases, the underdamped response occurs most frequently in control systems. Hence a number of terms are used to describe the underdamped response quantitatively. Equations for some of these terms are listed below for future reference. In general, the terms depend on τ and/or ξ. All these equations can be derived from the time response as given by Eq. (5.19); however, the mathematical derivations are left to the reader as exercises.

1. Overshoot. Overshoot is a measure of how much the response exceeds the ultimate value following a step change and is expressed as the ratio A/B in Fig. The overshoot for a unit step is related to ξ by the expression

   Overshoot = $\exp\left(\frac{-\pi\xi}{\sqrt{1-\xi^2}}\right)$……..5.20



2. Decay ratio. The decay ratio is defined as the ratio of the sizes of successive peaks and is given by C/A in Fig. The decay ratio is related to ξ by the expression

   Decay ratio = $\exp\left(\frac{-2\pi\xi}{\sqrt{1-\xi^2}}\right) = (overshoot)^2$……..5.21
3. Rise time. This is the time required for the response to first reach its ultimate value and is labeled t_r in Fig. The reader can verify from Fig. that t_r increases.
4. Response time. This is the time required for the response to come within +5 or -5 percent of its ultimate value and remain there. The response time is indicated in Fig. The limits +5 or -5 percent are arbitrary, and other limits can be used for defining a response time.
5. *Period of oscillation.* From Eq. 5.19, the radian frequency (radians/time) is the coefficient of t in the sine term; thus,

   Radian frequency $\omega = \frac{\sqrt{1-\xi^2}}{\xi}$ ……5.22

   Since the radian frequency ω is related to the cyclical frequency f by$\omega = 2\pi f$, it follows that

   $f = \frac{1}{T} = \frac{1}{2\pi}\frac{\sqrt{1-\xi^2}}{\xi}$………5.23

   Where T is the period of oscillation (time/cycle). In terms of Fig. T is the time elapsed between peaks. It is also the time elapsed between alternate crossings of the line Y =1.
6. Natural period of oscillation. If the damping is eliminated the system oscillates continuously without attenuation in amplitude. Under these “natural” or undamped conditions, the radian frequency is $1/\tau$, as shown by Eq. (5.22) when $\xi = 0$. This frequency is referred to as the natural frequency ω_n.

   $\omega_n = 1/\tau$……5.24

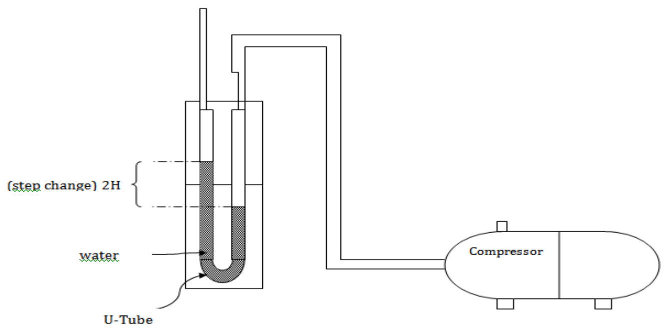
   The corresponding natural cyclical frequency f_n.and period T_n. n are related by the expression

   $f_n = \frac{1}{T_n} = 1/2\pi\,\tau$……5.25

   Thus, t has the significance of the undamped period.

   From Eqs. (5.23) and (5.25), the natural frequency is related to the actual frequency by the expression

$$\frac{f}{f_n} = \sqrt{1-\xi^2} \ldots\ldots 5.26$$



Procedure:

- Connect the manometric tube to the compressed air supplier, keep the pressure regulating valve in the closed position.
- Connect the manometric tube to the one side of the manometer.
- Allow the regulated compressed air pressure to the one side of the manometer. (apply air mercury may be thrown out form the manometer.)
- Allow sufficient time for the manometer reading to stabilize. Note down the height of the mercury thread in one of the limbs of the manometer.
- At time t=0 withdraw the air press and note down the height of the mercury thread in the same limb (upward and downward) where the reading was taken earlier. Remember that the mercury thread will move very fast and the reading has to be taken in very short time.
- Repeat the procedure for different step sizes of press.

Observations:

Length of the mercury thread in the manometer(L) =

Viscosity of the mercury at the room temp.(μ) = cP = kg/ms

Inside diameter of manometer tube (d) = cm

Density of fluid (ρ) = kg/m^3

Observation Table:

Sr. No.	Time	Height of peak	Height of through	y(t)/A
01				
02				
03				
04				
05				
06				
07				
08				
09				
10				
11				
12				
13				
14				
15				

Calculation:

From graph: A = and B =

Overshoot = A/B =

Decay ratio = $(\text{Overshoot})^2$ =

Damping factor =

Overshoot = $\exp\left(\frac{-\pi\xi}{\sqrt{1-\xi^2}}\right)$

$\xi =$

Time constant τ =

$\frac{2\pi\tau}{\sqrt{1-\xi}} = T$ where $T = 1$

Theoretical calculation

$\tau = \sqrt{\frac{2L}{3g}}$ S

$\xi = (8\mu|\rho D^2) * \sqrt{\frac{3L}{2g}}$

Overshoot = $\exp\left(\frac{-\pi\xi}{\sqrt{1-\xi^2}}\right)$

Decay ratio = $(\text{Overshoot})^2$ =

Graph: y(t)/A v/s time

Result:

	Practically (Graph)	Theoretical
Overshoot		
Decay ratio		
Damping factor		
Time constant		

Conclusion:

Calibration of Thermocouple

Aim: To study the calibration setup of Thermocouple.

Theory:

In RTD there is change in material resistance as a function of temperature. Such a resistance change is considered a variable parameter property in the sense that the measurement of resistance, & thereby temperature, requires external power sources. There exists another dependence of electrical behavior of materials on temperature that forms the basis of a large percentage of all temperature measurement. This effect is characterized by a voltage-generating sensor in which an electromotive force (emf) is produced that is proportional to temperature. Suchan emf is found to be almost linear with temperature & very repeatable for constant materials. Devices that measure temperature on the basis of this thermoelectric principle are called thermocouples (TCs).

Thermoelectric Effects:-
The basic theory of the thermocouple effect is found from a consideration of the electrical & thermal transport properties of different metals. In particular, when a temperature differential is maintained across a given metal, the vibration of atoms & motion of electrons is affected so that a difference in potential exists across the material. This potential difference is related to the fact that electrons in the hotter end of the material have more thermal energy than those in the cooler end, &thus tend to drift toward the cooler end. This drift varies for different metals at the same temperature because of differences in their thermal conductivities. If a circuit is closed by connecting the ends through another conductor, a current is found to flow in the closed loop. The proper description of such an effect is to say that an emf has been established in the circuit & is causing the current to flow. Fig. shows a pictorial representation of this effect, called the Seebeck effect, in which two different metals, A & B, are used to close the loop with the connecting junctions at temperatures T1 & T2. We could not close the loop with the same metal because the potential across each leg would be the same, & thus no net emf would be present. The emf produced is proportional to the difference in the temperature between the two junctions. Theoretical treatments of this problem involve the thermal activities of the two metals.

SEEBECK EFFECT:
Using solid-state theory, the above-mentioned situation may be analyzed to show that its emf can be given by an integral over temperature

$$\varepsilon = \int_{T_1}^{T_2} (Q_A - Q_B)\, dT$$

Where,
ε = emf produced in volts
T1, T2 = junction temperatures in K
QA, QB = thermal transport constants of the two metals

The equation, which describes the Seebeck effect, shows that the emf produced is proportional to the difference in temperature & further, to the difference in the metallic thermal transport constants. Thus, if the metals are the same, the emf is zero, & if the temperatures are the same, the emf is also zero.

In practice, it is found that the two constants, QA & QB, are nearly independent of temperature & that an approximate linear relationship exists as

ε = α (T2 – T1)

Where,
α = constant in Volt/K
T1, T2 = junction temperatures in K
However, the small but finite temperature dependence of QA& QB is necessary for accurate considerations.

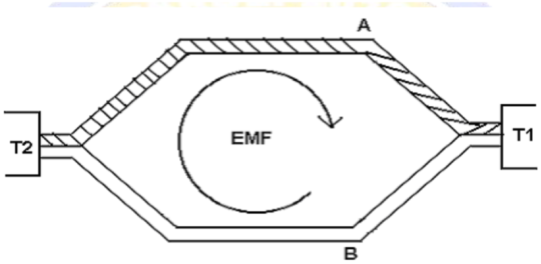


Fig: Seeback Effect

PELTIER EFFECT:
AN interesting & sometimes useful extension of the same thermoelectric properties occurs when the reverse of the Seebeck effect is considered. In this case, we construct a closedloop of two different metals, A & B, as before. Now, however, an external voltage is applied to thesystem to

cause a current to flow in the circuit, as shown in Fig.3. Because of the different electrothermal transport properties of the metals, it is found that one of the junctions will be heated & theother cooled; that is, the device is a refrigerator! This process is referred to as the Peltier effect.

Some practical applications of such a device, such as cooling small electronic parts, have been employed.

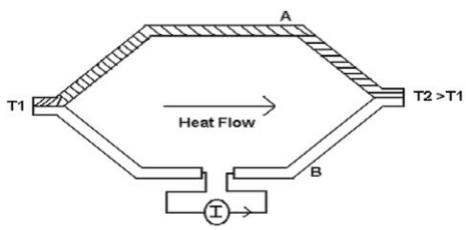


Fig: Peltier Effect

THERMOCOUPLE CHARACTERISTICS:

To use the Seebeck effect as the basis of a temperature sensor, we need to establish ade finite relationship between the measured emf of the thermocouple & the unknown temperature. We see first that one temperature must already be known because the Seebeck voltage isproportional to the difference between junction temperatures. Furthermore, every connection ofdifferent metals made in the thermocouple loop for measuring devices, extension leads, & so onwill contribute an emf, depending on the difference in metals & various junction temperatures. Toprovide an output that is definite with respect to the temperature to be measured, an arrangement isused. This consists the measurement junction, Tm, which is exposed to the environment whosetemperature is to be measured. This junction is formed of metals A & B as shown. Two otherjunctions are then formed to a common metal, C, which then connects to the measurementapparatus. The "reference" junctions are held at a common, known temperature Tr, the referencejunction temperature. When an emf is measured, problems such as voltage drops across resistiveelements in the loop must be considered. In this arrangement, an open-circuit voltage is measured (at high impedance) that is then a function of only the temperature difference (Tm – Tr) & the typeof metals A & B. The voltage produced has a magnitude dependent on the absolute magnitude ofthe temperature difference & a polarity dependent on which temperature is larger, reference or measurement junction. Thus, it is not necessary that the measurement junction have a higher temperature than the reference junctions, but both magnitude & sign of the measured voltage mustbe noted.

To use the thermocouple to measure a temperature, the reference temperature must be known& the reference junctions must be held at the same temperature. The temperature should beconstant, or at least not vary much. In most industrial environments, this would be difficult to achieve if the measurement junction & reference junction were close. It is possible to move thereference junctions to a remote location without upsetting the measurement process by the use ofextension wires. A junction is formed with the measurement system, but to wires of the same typeas the thermocouple. These wires may be stranded & of different gauges, but they must be of thesame type of metal as the thermocouple. The extension wires now can be run a significant distanceto the actual reference junctions.

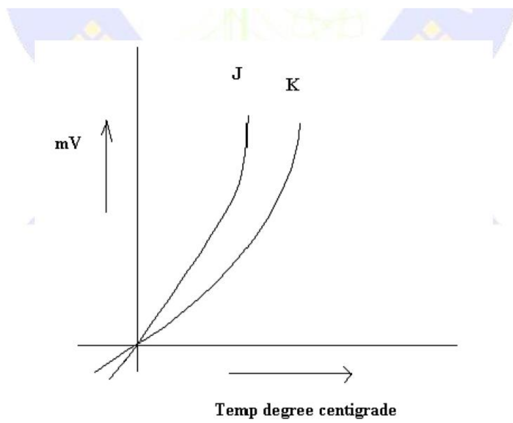
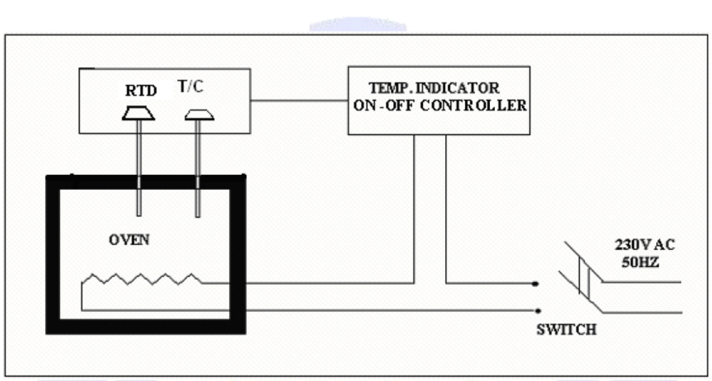


Fig: Thermocouple Characteristics

RTD, THERMOCOUPLE CALIBRATION SETUP

The RTD, Thermocouple calibration setup consists of a muffle furnace. It also consists ofmV/Temperature Display, Temperature Controller, Solid State Relay, and Insertion Points for Thermocouples.

Basically, this unit is used to calibrate the different type of Temperature sensors (E.g. Thermocouples, RTD, Thermistor etc.).



Experimental Setup: RTD, thermocouple calibration setup

CALIBRATION PROCEDURE:

1. Turn on the MAINS SWITCH, HEATER and FAN.

2. If the temperature is to be set below 500 °C keep heater s/w as LOW and for higher temperature keep it as HIGH.

3. Insert the thermocouple and RTD through insertion points in the furnace.

4. Give the output of thermocouple to the input points provided on the front panel.

5. Switch ON multimeter and select resistance measurement. Connect RTD lead wires to multimeter.

6. Select a temperature set point (up to 150 °C) using push button & knob provided.

7. Observe the temperature and corresponding mV output of thermocouple on display using selector switch and resistance (Ω) on multimeter.

8. Also verify the observations using the standard charts provided.

9. Repeat the procedure for different set points of temperatures.

10. Take into consideration the ambient temperature effect & compensate the corresponding mV values while checking the thermocouples.

11. The temperature inside the furnace can go up to 500oC.twoK type thermocouples and Pt100 RTD is provided.

Observation Table:

Sr No.	Temperature (°C)	Heating		Cooling	
		K type (mV)	RTD(Ω)	K type (mV)	RTD(Ω)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					

Graphs:

Temp and Resistance (Ω) vs Temp

Plot graph of emf (mV) vs Temp

Results:

	Final Temperature (℃)	K type (mV)	RTD(Ω)
Heating			
Cooling			

Conclusion:

Temperature Control Trainer

Description

The Temperature control trainer is designed for teaching the basic temperature control principles study in chemical and instrumentation engineering. For ease of understanding, the product is described with its major components.

INTRODUCTION

Temperature control loops are usually moderately slow because of the sensor lags and the process heat transfer lags. PID controllers are often used. Proportional band setting are fairly low, depending on temperature transmitter spans and control valve sizes. The reset time is of the same order as the process time constant; i.e., the faster the process, smaller τ_I can be set. Derivative time is set something like one-fourth the process time constant, depending on noise in the transmitter signal.

THE CONTROL SYSTEM

A liquid stream at a temperature T_i enters a shell (shell & tube) at a constant flow rate. It is desired to maintain (or control) the temperature in the Heat Exchanger at T_R by means of the controller. If the measured temperature T_m differs from the desired temperature T_R, the controller senses the difference or error, $\varepsilon = T_R - T_m$, and changes the control valve position in such a way to reduce the magnitude of ε.

COMPONENTS OF A CONTROL SYSTEM:

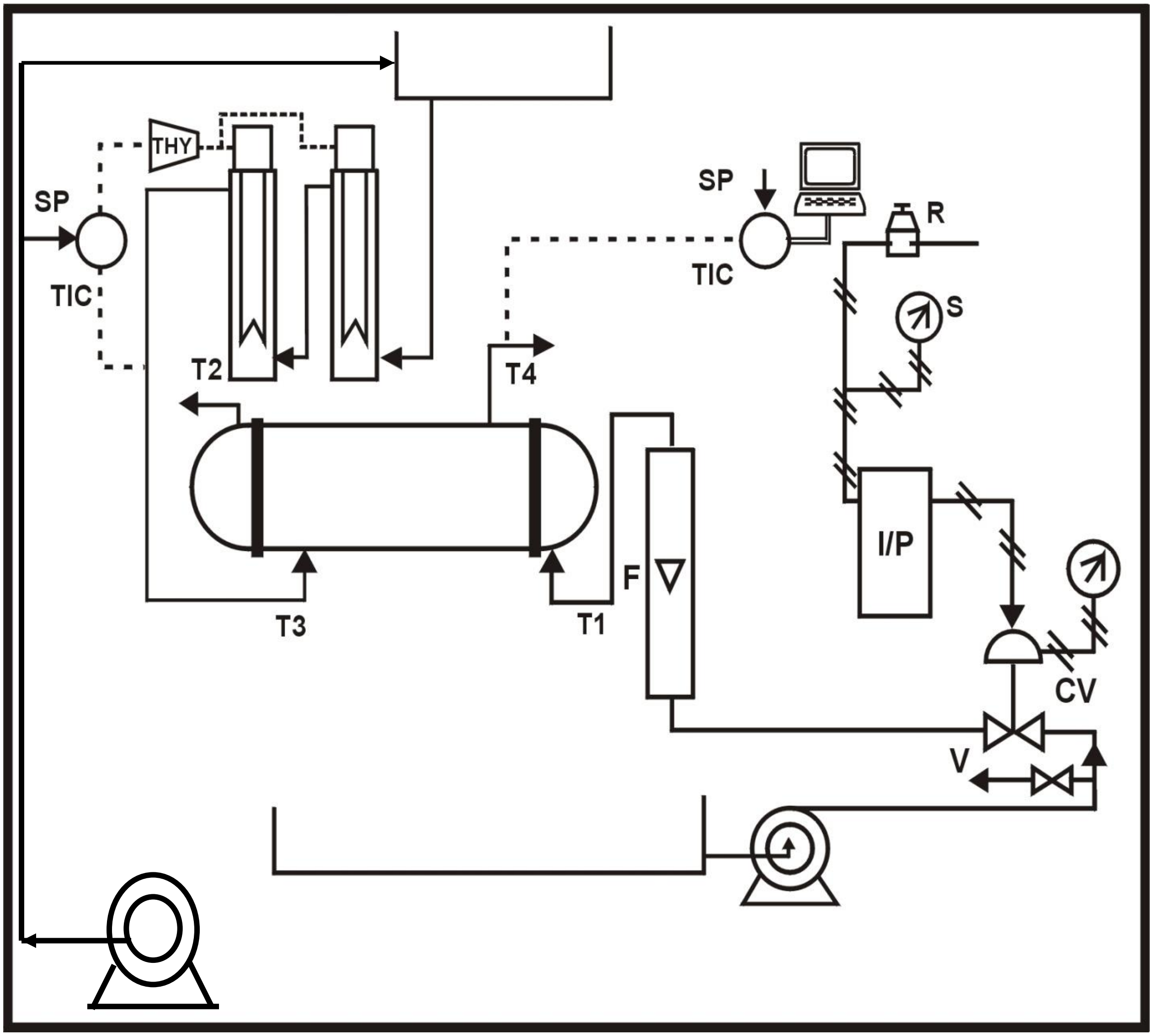


Figure 1. TEMPERATURE CONTROL TRAINER

The system shown may be divided into the following components:

TT	Temperature Transmitter
THY	Thyrister Drive fie Heater
F	Rotameter
SP	Set Point
TIC	Temperature Indicator Controller

BLOCK DIAGRAM

For computational purposes, it is convenient to represent the control system shown in Figure 1 by means of the block diagram shown in Figure 2. Such a diagram makes it much easier to visualize the relationships among the various signals.

Set Point : The set point is synonym for the desired value of the controlled variable.

Load : The load refers to a change in any variable that may cause the controlled variable of the process to change.
In the example, the inlet flow of water is a load variable.

The control system shown in Figure 2 is called a closed loop system or a feedback system because the measured value of the controlled variable is returned to of "fed back" to a device called the comparator. In the comparator, the controlled variable is compared with the desired value or set point. If there is any difference between the measured variable and the set point, an error is generated; this error enters a controller, which in turn adjusts the final control element in order to return the controlled variable to the set point.

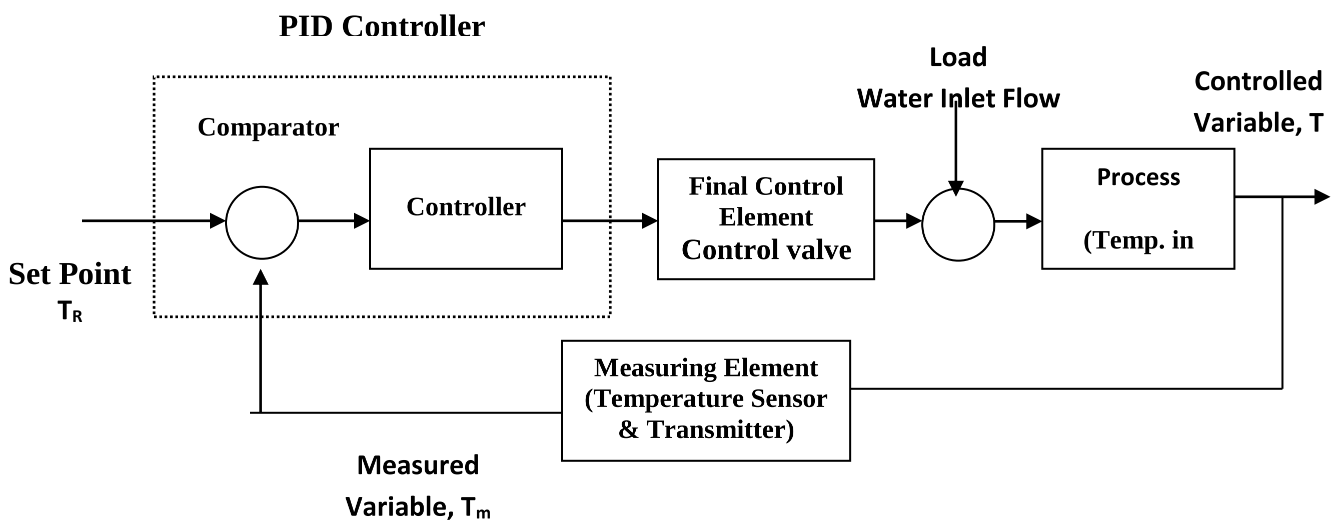


Figure 2. Block Diagram of a Temperature Control System

Functioning of the System

Figure 1 shows that a temperature sensor is used to measure the temperature of water Inlet to the Heat Exchanger, According to temperature give the output signal to the Heater temperature controller, which produces an output in the range of 4-20 mA, which is a linear function of the input. The output of the transducer enters the Heater temperature controller where it is compared to the set point to produce an error signal. The controller converts the error to an output in the range of 4 -20 mA according to the control law (P, PI, PD, PID or On-Off) stored in the memory of the controller. The output of the controller enters the Thyrister drive, which produces an output, which is a linear function of the input. Finally, the output of the Thyrister drive is sent to the heater, which adjusts the flow of heat to the water. The external power of 3 Phase is required for Heater and Controller. The external power of 3 Phase is required for Heater and Controller.

Figure 1 & 2 shows that another temperature sensor is used to measure the temperature of water outlet of the Heat Exchanger, According to temperature give the output signal to the temperature controller, which produces an output in the range of 4-20 mA, which is a linear function of the input. The output of the transducer enters the temperature controller where it is compared to the set point to produce an error signal. The controller converts the error to an output in the range of 4 -20 mA according to the control law (P, PI, PD, PID or On-Off) stored in the memory of the controller. The output of the controller enters the I-P Converter, which produces an output, which is a linear function of the input. Finally, the output of the I-P Converter is sent to the Control Valve, which adjusts the flow of cold water.

To see how the components interact with each other, consider the process to be operating at steady state with the outlet temperature of water from the tank is equal to the set point. If the inlet flow rate from the tank increases, the following events occur. Immediately the temperature sensor & temperature transmitter detects a decrease in the temperature of the water in the tank and produces a change in the signal to the controller. As soon as the controller detects decrease in the temperature, relative to the set point, the controller output increases according to the control action chosen. The increase in signal to the converter causes the output from the converter to increase and increase the flow of heat to the water. The increased flow of heat will eventually increase the temperature of the water move it towards the set point. From this quantitative description, we see that the flow of signals from one component to the next is such that the temperature of water should return to the set point. In a well-tuned control system, the response of the temperature will oscillate around the set point before coming to steady state.

STARTUP PROCEDURE:

⇒ Connect the air compressor line to the experimental control trainer. Shut off the air supply valve to the trainer.

⇒ Start the air compressor by providing 3 – phase electric supply to the compressor. Close the air discharge valve while the compressor is started. Fill the air inside the compressor cylinder.

⇒ Fill the water supply tank at the bottom of the trainer full with the fresh clean water. Make sure that drain valve is closed.

⇒ Fill the overhead water supply tank for heater tanks full during whole experiment. Also make continuous watch on the level of the tank. This tank should never going to be empty till experiment runs. Fill the tank by Switch on the pump .

⇒ After pressure of air inside compressor has build up sufficient (around 6-7 kg/cm^2) open the discharge valve of compressor and supply valve to the trainer.

⇒ Apply 20 psi (or 1.4 $kg/cm^{2)}$ to the E/P Converter by regulating pressure from air filter cum regulator. Lock the regulator by pressing ring of it.

⇒ Open the discharge gate valve provided at the outlet of the overhead tank to supply water to the heater tank.

⇒ Give supply of **3 Phase + 1 Neutral + Ear thing (3 phase)** to the trainer by the three plugs provided. Switch ON Power supply switch.

⇒ As water starts coming out from the overhead tank by passing through the heater tanks, shell side of exchanger to the drain, adjust the set point of the hot water by heater controller. Initially feed set point of it to nearly 50 ^{0}C by Heater Controller. (Remove any air from the system by opening the gate valve of the heat exchanger shell side)

⇒ Switch on the pump by the push button provided with indicating lamp. Make sure that bypass valve is fully open.

⇒ Now adjust the set point of the PID Controller to the 45 ^{0}C and also make necessary P, I, D settings as per shown in the manual of PID Controller. Now close the bypass valve slightly to supply cold water to the tube side of the exchanger through control valve and Rotameter. Make sure that the set point of PID Controller should be 5 – 10 ^{0}C less than the heater controller.

⇒ Make sure that needle valve of Rotameter is fully open during the whole operation.

⇒ Apply a new set point (in between the range of ambient to 75 ^{0}C) to the PID Controller and read the behavior of the loop. Adjust the drain valve of the overhead tank according to the set point.

⇒ Refer the PID Controller manual for operating the controller.

⇒ To start the software read the PID Control Trainer Software manual supplied.

⇒ Do the experiments as indicated in the temperature control trainer experiment manual.

SHUTDOWN PROCEDURE:

- First of all OFF the heater by mains switch and reduce the set point of the heater controller below 20 ^{0}C. Make sure that the water from the overhead tank is running continuously till it totally empty.
- Close the air supply to the E/P Converter/control valve by closing the regulator provided.
- Close the gate valve located at the inlet pipe line of Heater.
- Switch off the air compressor and shut off the discharge valve of it. Drain the filled air from the cylinder of compressor by opening the drain coke at the bottom of the compressor. Close the air supply valve to the control trainer.
- Adjust the set point of the PID Controller to a lower value (around 20 ^{0}C).
- Open the drain valve of Heater tank and drain the water inside the heater tank.
- Stop communication from the computer and shut down it.
- Switch off power supply to the trainer.

PRECAUTIONS:

⇒ For proper operation read the instruction provided and then follows it step by step.
⇒ Do not apply very high set point to the PID Controller (not above 70 ^{0}C) as it may damage the heat exchanger / heater tank.
⇒ Do not run heater for a longer time.
⇒ Always run the heater when the flow of water is continuous through the heater tank.
⇒ Do not apply higher pressure to E/P Converter (greater than 1.4 kg/cm^2) as it may damage it. Also the lesser pressure (less than 1.4 kg/cm^2) may not give accurate functioning of it.
⇒ Use fresh and clean water always in the water supply tanks.
⇒ Remove all water from the tank after experiment is over.
⇒ Clean pump regularly.
⇒ Do not alter the wiring of the instrument.
⇒ Do not alter or modify any component of the trainer.
⇒ Carefully read the manuals of each component fitted in the trainer and understand the product working. Refer the individual manual of each for proper maintenance and precautions.
⇒ If possible put trainer in Air-conditioned room. The computer should not be farther than the 5 meter from the trainer.
⇒ Do not put instrument idle for a longer time. Run it once in a week.
⇒ Give routine maintenance to it.

⇒ Remove dust periodically from the trainer.

⇒ Any problem encountered during the use of the setup, first refer instruction manual. If the problem persists, contact us immediately. We provide support for your specific questions or any up gradation.

ROUTINE MAINTENANCE:

⇒ Replace water in case suspended particles are observed. (It is advised to use clean distilled water to improve the reliability of the product. Any suspended particles in water may clog the pump strainer causing no discharge through the pump.)

⇒ Check the working of control panel for process parameter display.

⇒ Disconnect the electric supply to the control panel when not in use.

⇒ Clean pump strainer in sequence as mentioned below:

➢ Remove the pump by lifting the support of the pump from the tank.

➢ Gently remove the strainer at the suction of the pump by rotating it anti clockwise.

➢ Remove the mesh from the strainer. Clean and wash the mesh thoroughly.

➢ Fix the mesh back to its location properly.

➢ Replace the pump in tank.

➢ Refer the pump manual for detail of troubleshooting.

⇒ Remove any excess of water from the heater tank.

⇒ Drain out excess water from the shell and tube heat exchanger.

⇒ Do not start heater without supply of water to the tank.

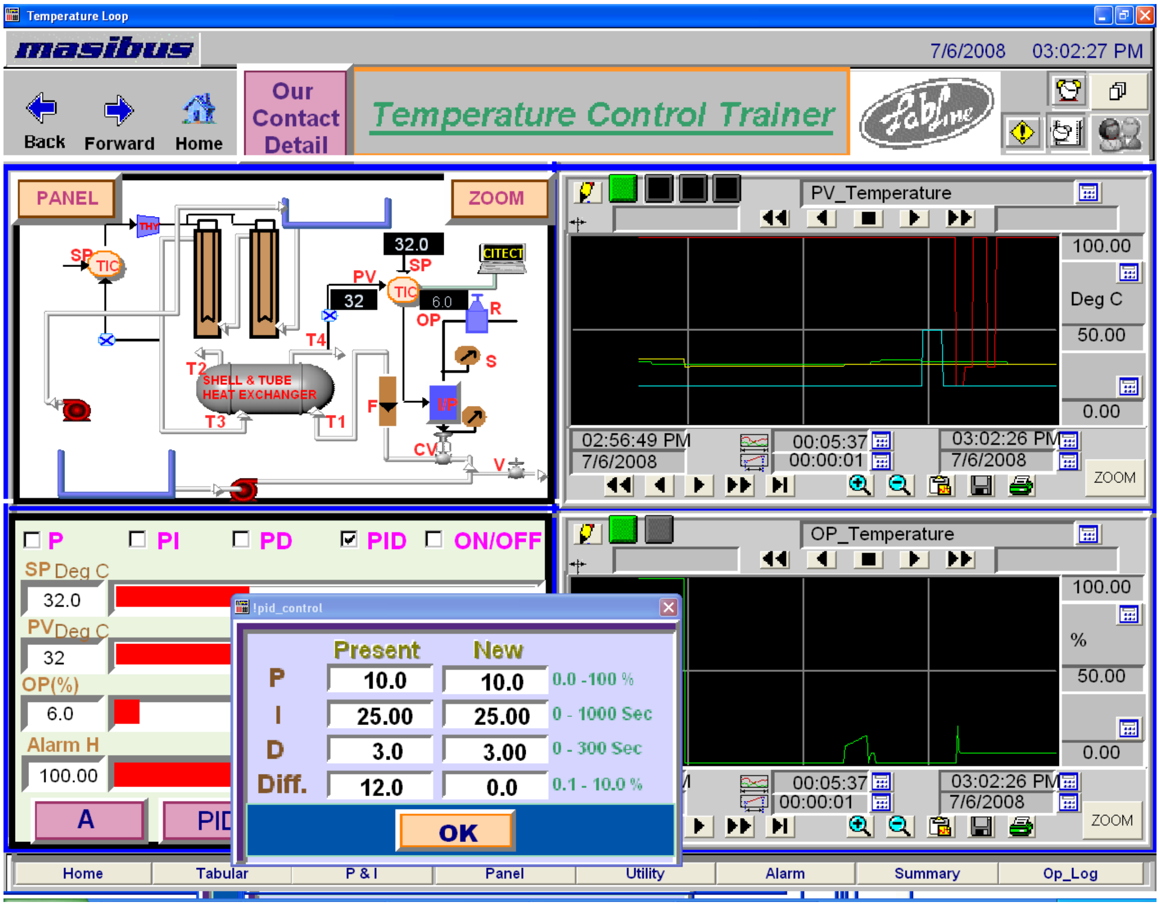
CLOSED LOOP (AUTO MODE) CONTROL

(Proportional + Integral + Derivative Control)

AIM : To Study the Closed Loop (Auto Mode) Control (Proportional + Integral + Derivative Control).

PROCEDURE:

- ⇒ Start the equipment as mentioned in the startup procedure above.
- ⇒ Adjust the set point of Heater temperature controller approx. 60 Deg. C
- ⇒ Adjust the opening (approx. 20 %) of the disturbance valve provided on the Heater tank and do not alter it throughout the course of the experiment.
- ⇒ Select the Auto option by pressing the **AUTO/MANUAL** button provided on the main screen. The button should indicate **AUTO** when the controller is in Auto Control mode.
- ⇒ Allow the system to attain the steady state at the initial set point 45 Deg C Value of temperature.
- ⇒ Choose the Save As option in the File menu and save the file by giving appropriate name.
- ⇒ Choose the **Proportional + Integral + Derivative (PID)** Control action from the Menu/ Radio Button on the main screen.
- ⇒ Click on to the **PID** button and enter the desired value of proportional band, reset time and rate time in the popped up screen and apply it.
- ⇒ Allow the system to achieve the steady state and observe the path followed by the process variable to reach the set point. Change the value of proportional band, reset time as well as rate time and observe the same.
- ⇒ Load change (regulatory problem) may also be applied by changing the opening position of the disturbance valve provided on the pressure tank. / Set point change may also be applied by changing the set point (servo problem) using the up/ down arrow provided besides the indicator of set point or directly insert the value of desired set point in the set point value box by inserting the cursor.
- ⇒ Shut down the equipment as mentioned in the shutdown procedure above.
- ⇒ The value of load change / set point change should be approximately 20% of the range to obtain proper response otherwise the controller may track to its set point without any overshoot/ undershoot.
- ⇒ In following window we can see screen shot for *Proportional + Integral* + Derivative *Control* mode.



OBSERVATIONS:

Observe that at any value of proportional, reset time & rate time the process variable reaches the set point value.

Observe the effect of load & set point change on the behavior of the system.

Level Control Trainer

Description

The Level control trainer is designed for teaching the basic level control principles study in chemical and instrumentation engineering. For ease of understanding, the product is described with its major components.

INTRODUCTION

Most liquid levels represent material inventory used as surge capacity. In these cases it is relatively unimportant where the level is, as long as it is between some maximum and minimum values. Therefore, proportional controllers are often used on level loops to give smooth changes in flow rates and to filter out fluctuations in flow rates to downstream units.

THE CONTROL SYSTEM

A liquid stream entering the tank maintains the level of the liquid at a height Li. It is desired to maintain (or control) the height of the liquid at LR by means of the controller. If the measured height Lm differs from the desired height LR, the controller senses the difference or error $\varepsilon = LR - Lm$, and changes the valve position in such a way that the desired liquid height LR is obtained in the tank.

COMPONENTS OF A CONTROL SYSTEM:

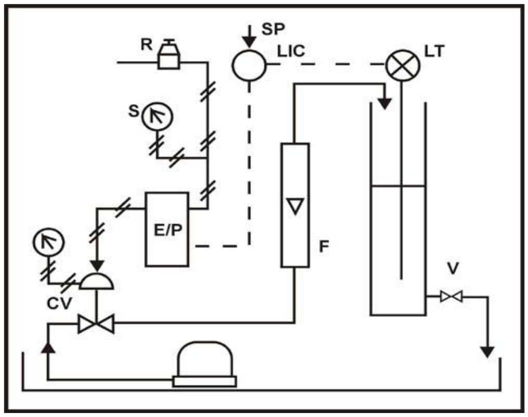


Figure 1. LEVEL CONTROL TRAINER

The system shown may be divided into the following components:

LT	Level Transmitter
E/P	Electric to Pneumatic Converter
V	Bypass Valve
CV	Pneumatic Control Valve
F	Rotameter
R	Air Pressure Regulator
S	Supply Pressure Gauge (I/P)
SP	Set Point
LIC	Level Indicator Controller

BLOCK DIAGRAM

For computational purposes, it is convenient to represent the control system shown in Figure 1 by means of the block diagram shown in Figure 2. Such a diagram makes it much easier to visualize the relationships among the various signals.

Set Point: : The set point is synonym for the desired value of the controlled variable.

Load: : The load refers to a change in any variable that may cause the controlled variable of the process to change.

In the example, the outlet (drain) valve position is a load variable.

The control system shown in Figure 2 is called a closed loop system or a feedback system because the measured value of the controlled variable is returned to of "fed back" to a device called the comparator. In the comparator, the controlled variable is compared with the desired value or set point. If there is any difference between the measured variable and the set point, an error is generated; this error enters a controller, which in turn adjusts the final control element in order to return the controlled variable to the set point.

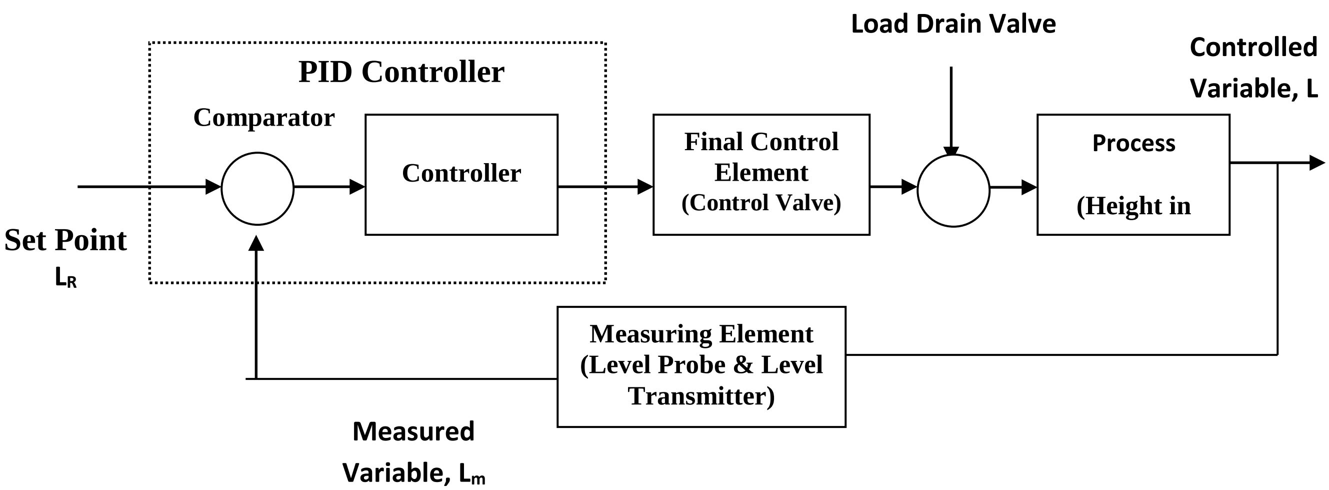


Figure 2. Block Diagram of a Level Control System

Functioning of the System

Figure 1 & 2 shows that a capacitance type level probe is used to measure the level of water in the tank; the signal from the level probe is sent to the transducer (level transmitter), which produces an output in the range of 4-20 mA, which is a linear function of the input. The output of the transducer enters the controller where it is compared to the set point to produce an error signal. The controller converts the error to an output in the range of 4 -20 mA according to the control law (P, PI, PD, PID or On-Off) stored in the memory of the controller. The output of the controller enters the I/P converter, which produces an output in the range of 3-15 psig, which is a linear function of the input. Finally, the output of the converter is sent to the top of the control valve, which adjusts the flow of water to the tank. The control valve used here is linear and is pressure-to-open type. The external power of 230 V AC is required for controller, I/P converter and level transmitter. A source of 20-psig airs is needed for the converter.

To see how the components interact with each other, consider the process to be operating at steady state with the outlet flow rate through the tank is equal to the set point. If the outlet flow rate from the tank increases, the following events occur. Immediately the level probe & level transmitter detects a decrease in the level of the water in the tank and produces a change in the signal to the controller. As soon as the controller detects decrease in the level, relative to the set point, the controller output increases according to the control action chosen. The increase in signal to the converter causes the output from the converter to increase and open the valve in order to increase the flow of water. The increased flow will eventually increase the level of water in the tank and move it towards the set point. From this quantitative description, we see that the flow of signals from one component to the next is such that the level of water in the tank should return to the set point. In a well-tuned control system, the response of the level will oscillate around the set point before coming to steady state.

STARTUP PROCEDURE:

- ⇒ Connect the air compressor line to the experimental control trainer. Shut off the air supply valve to the trainer.
- ⇒ Start the air compressor by providing 3-phase electric supply to the compressor. Close the air discharge valve while the compressor is started. Fill the air inside the compressor cylinder.
- ⇒ Fill the water supply tank at the bottom of the trainer full with the fresh clean water. Make sure the drain valve is closed.
- ⇒ After pressure of air inside compressor has build up sufficient (around 6 – 7 Kg/cm^2) open the discharge valve of the compressor and valve to the trainer.
- ⇒ Apply 20 psi (or 1.4 Kg/cm$^{2)}$ to the E/P converter by regulating pressure from air filter cum regulator. Lock the regulator by pressing ring of it.
- ⇒ Give the supply of 230 V AC to the trainer by three plugs pin provided. Switch ON the power supply.
- ⇒ Switch on the PID and put the toggle switch towards Level side.
- ⇒ Switch on the pump by the toggle switch provided with indicating lamp. Make sure the bypass valve is fully open.
- ⇒ Now adjust the set point of the PID controller to the 250 mmWC and also make necessary P, I, D. Setting as per shown in the manual of PID Controller.
- ⇒ Make sure the needle valve of Rotameter is fully open during whole operation. Also slight open the ball valve (drain/disturbance valve) provided on the bottom of the level tank so that excess water can drain out from the valve to the water supply tank.
- ⇒ In control panel a link is provided at the E/P converter input .so you can have Recorder output (in the range of 0 – 100 %) (4 – 20 mA) to which you can attach recorder of the same input type (i.e. 4 – 20 mA). The current meter on the top of the

panel indicates Control valve position, E/P Converter input, and transmitter output in the range 4 – 20 mA.

⇒ Apply the new set point to the PID Controller and read the behaviors of the loop. Adjust the drain valve of the level tank according to the set point

⇒ To start the software read the PID Control trainer software manual supplied..

⇒ Do the experiment as indicated in the level control trainer experiment manual.

⇒ Choose the Mode of Operation or Control action of interest, apply the disturbance/ change of set point and log the data to the computer and analyze it.

SHUTDOWN PROCEDURE:

⇒ Before shutting down the system after experiment, Shutdown the programme to break the link between PID Controller and the Computer.

⇒ Switch off the PID and Pump.

⇒ Close the air supply to the E/P Converter/Control valve.

⇒ Now shut off the pressure regulator provided for the I/P converter (fitted on the front panel) until the pressure gauge fitted along with it indicates 0 kg/ cm^2 (g) pressure.

⇒ Switch off the air compressor and shut off the discharge valve of it. Drain the filled air from the Cylinder of compressor by opening the drain coke at the bottom of the compressor. Close the air supply valve to the control trainer. Switch off the power supply to the trainer.

PRECAUTIONS:

⇒ For proper operation read the instructions provided and then follow it step by step.

⇒ Do not apply very high set point to the PID Controller, as it may damage the level tank / transmitter after long time though the tank is tested to higher level.

⇒ Do not apply higher pressure to E/P Converter (greater than 1.4 Kg/cm^2) as it may damage it. Also the lesser Pressure (lesser than 1.4 Kg/cm^2) may not give accurate functioning of it.

⇒ Do not change the link position of the control panel terminals.

⇒ Use fresh and clean water always in the water supply tank.

⇒ Remove all water from the tank after experiment is over.

⇒ Clean pump regularly.

⇒ Do not alter the wiring of the instrument.

⇒ Do not alter or modify any components of the trainer.

⇒ Carefully read the manuals of each component fitted in the trainer and understand the product working.

⇒ If possible put trainer in Air-conditioned room. The computer should not be farther than 5 meter from the trainer.

⇒ Do not put instrument idle for longer time. Run it once in a week.

- ⇒ Give routine maintenance to it.
- ⇒ Remove dust periodically from the trainer.
- ⇒ Any problem encountered during the use of the set-up, first refer instruction manual. If the problem persists, contact us immediately. We provide support for your specific questions or any up gradation.

ROUTINE MAINTENANCE:

- ⇒ Replace water in case suspended particles are observed. (It is advised to use clean distilled water to improve the reliability of product. Any suspended particles in water may clog the pump strainer causing no discharge through the pump.)
- ⇒ Check the working of control panel when not in use.
- ⇒ Disconnect the electric supply to the control panel when not in use.
- ⇒ Clean pump strainer in sequence as mentioned below.
    - ➢ Remove the pump by lifting the support to the pump from the tank.
    - ➢ Gently remove the strainer at the suction of the pump by rotating it anti clockwise.
    - ➢ Remove the mesh from the strainer. Clean and wash the mesh thoroughly.
    - ➢ Fix the mesh back to location properly.
    - ➢ Replace the pump in a tank.
- ⇒ If the variation in actual level and transmitter signal is more than three percent, calibrate level transmitter in sequence as mention below.
    - ➢ Open the cover of level transmitter.
    - ➢ Close the Drain valve fully.
    - ➢ Switch on the power supply to the unit and fill the process tank up to water touch to the pipe. Adjust zero range by adjusting the pot.
    - ➢ Fill tank up to maximum span range and adjust the max. Pot.
    - ➢ Close the transmitter cover.

CLOSED LOOP (AUTO MODE) CONTROL
(Proportional Control)

AIM : To Study the Closed Loop (Auto Mode) Control (Proportional Control).

PROCEDURE:

⇒ Start the equipment as mentioned in the startup procedure above.

⇒ Adjust the opening (approx.50 %) of the disturbance valve provided at the bottom of the level tank.

⇒ Select the Auto option by pressing the **AUTO/MANUAL** button provided on the main screen. The button should indicate **AUTO** when the controller is in Auto Control mode.

⇒ Allow the system to attain the steady state at the initial set point (about 250).

⇒ Choose the Save As option in the File menu and save the file by giving appropriate name.

⇒ Choose the **Proportional (P)** Control action from the Menu Button on the main screen.

⇒ Click on to the **PID** button and enter the desired value of only proportional band in the popped up screen and apply it.

⇒ Allow the system to achieve the steady state and observe the offset between the process variable and set point. Change the value of proportional band observes the same.

⇒ Load change (regulatory problem) may also be applied by changing the opening position of the disturbance valve provided at the bottom of the level tank. / Set point change may also be applied by changing the set point (servo problem) using the up/ down arrow provided besides the indicator of set point or directly inserts the value of desired set point in the set point value box by inserting the cursor.

⇒ Shut down the equipment as mentioned in the shutdown procedure above.

⇒ The value of load change / set point change should be approximately 20% of the range to obtain proper response otherwise the controller may track to its set point without any overshoot/ undershoot.

OBSERVATIONS:

Observe that the offset decreases with decrease in the proportional band value.

Observe the effect of load & set point change on the behavior of the system.

Flow Control Trainer

Description

The Flow control trainer is designed for teaching the basic Flow control principles study in chemical and instrumentation engineering. For ease of understanding, the product is described with its major components.

INTRODUCTION

PI controllers are used in most flow loops. A wide proportional band setting (PB= 150) or low gain is used to reduce the effect of the noisy flow signal due to flow turbulence. A low value of integral or reset time (τ_I = 0.1 minutes/ repeat) is used to get very fast, snappy set point tracking. The dynamics of the process are usually very fast. The sensor sees the change in flow almost immediately. The control valve dynamics are the slowest element in the loop, so a small reset time can be used.

THE CONTROL SYSTEM

A liquid stream at a flow rate F_i passes through a pipe. It is desired to maintain (or control) the flow rate through the pipe at F_R by means of the controller. If the measured flow rate F_m differs from the desired flow rate F_R, the controller senses the difference or error $\varepsilon = F_R - F_m$, and changes the valve position in such a way that the desired flow rate F_R is obtained through the pipe.

COMPONENTS OF A CONTROL SYSTEM:

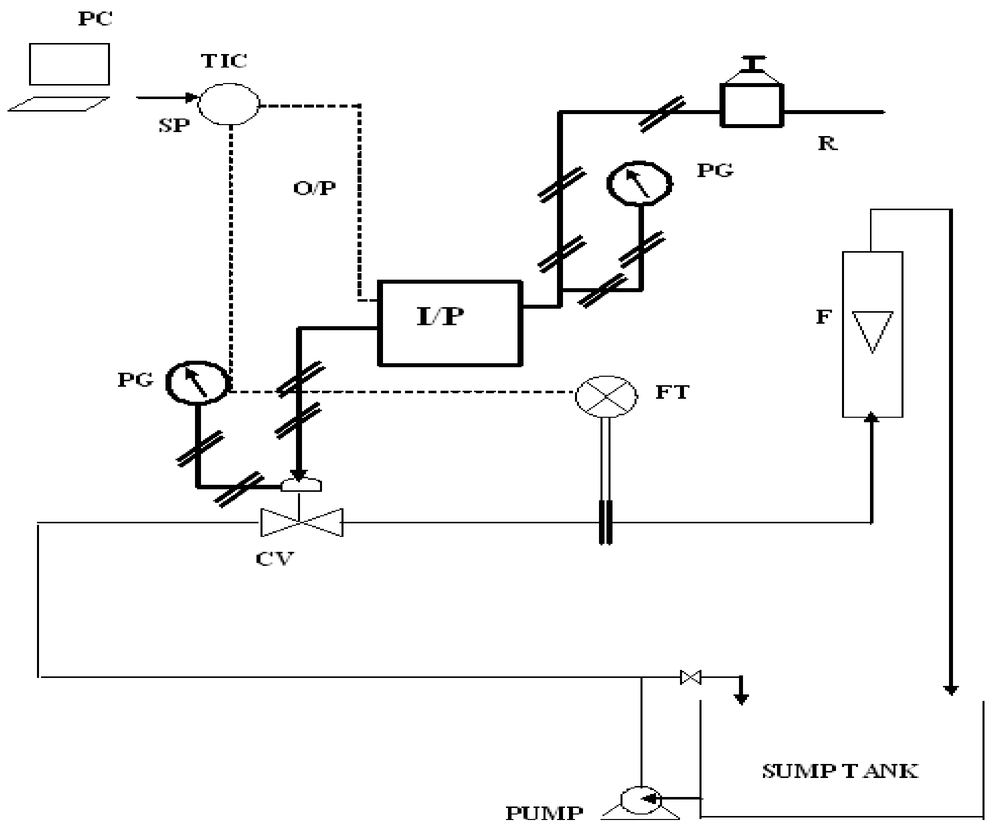


Figure 1. FLOW CONTROL TRAINER

The system shown may be divided into the following components:

FT	Orifice and Flow Transmitter
E/P	Electrical to Pneumatic Converter
V	Bypass Valve
CV	Pneumatic Control Valve
F	Rotameter
R	Air Pressure Regulator
S	Supply Pressure Gauge (I/P)
SP	Set Point
FIC	Flow Indicator Controller

BLOCK DIAGRAM

For computational purposes, it is convenient to represent the control system shown in Figure 1 by means of the block diagram shown in Figure 2. Such a diagram makes it much easier to visualize the relationships among the various signals.

Set Point: : The set point is synonym for the desired value of the controlled variable.

Load: : The load refers to a change in any variable that may cause the controlled variable of the process to change.

In the example, the inlet flow Fi is a load variable.

The control system shown in Figure 2 is called a closed loop system or a feedback system because the measured value of the controlled variable is returned to of "fed back" to a device called the comparator. In the comparator, the controlled variable is compared with the desired value or set point. If there is any difference between the measured variable and the set point, an error is generated; this error enters a controller, which in turn adjusts the final control element in order to return the controlled variable to the set point.

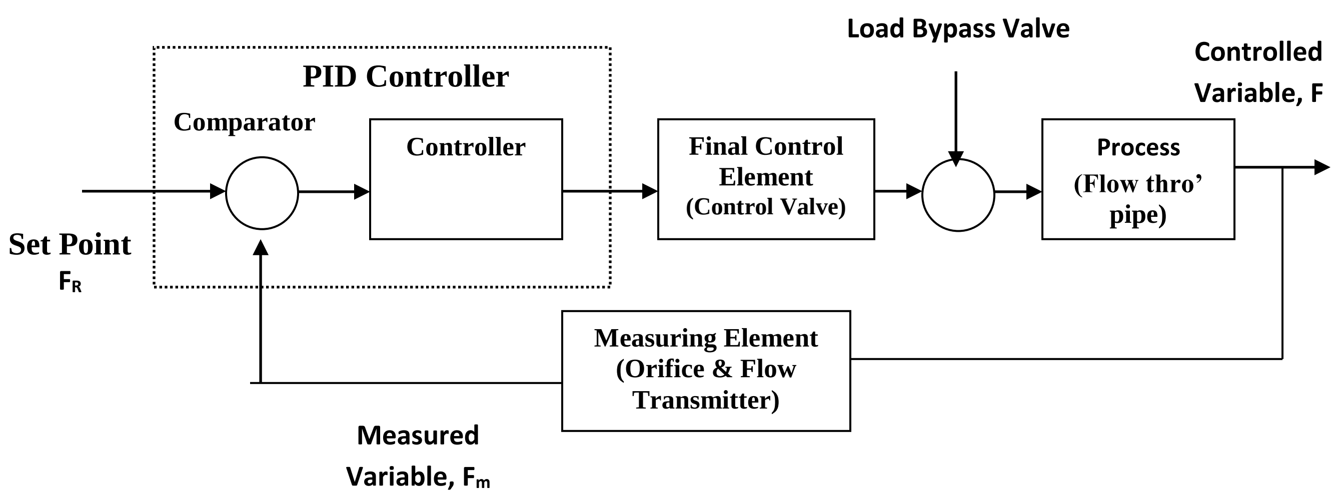


Figure 2. Block Diagram of a Flow Control System

Functioning of the System

Figure 1 & 2 shows that an orifice meter is used to measure the flow rate of water; the signal from the orifice meter is sent to the transducer (flow transmitter), which produces an output in the range of 4-20 mA, which is a **square root** function of the input. The output of the transducer enters the controller where it is compared to the set point to produce an error signal. The controller converts the error to an output in the range of 4 –20 mA according to the control law (P, PI, PD, PID or On-Off) stored in the memory of the controller. The output of the controller enters the I/P converter, which produces an output in the range of 3-15 psig, which is a linear function of the input. Finally, the output of the converter is sent to the top of the control valve, which adjusts the flow of water through the pipe & orifice meter. The control valve used here is linear and is pressure-to-open type. The external power of 230 V AC is required for controller and I/P converter and 24 V DC for flow transmitter. A source of 20-psig airs is needed for the converter. To see how the components interact with each other, consider the process to be operating at steady state with the outlet flow rate equal to the set point. If the upstream flow (pressure) of the process stream increases, the following events occur. Immediately the orifice & flow transmitter detects an increase in the outlet flow rate and produces a change in the signal to the controller. As soon as the controller detects rise in the flow rate, relative to the set point, the controller output decreases according to the control action chosen. The decrease in signal to the converter causes the output from the converter to decrease and close the valve in order to restrict the flow of water. The reduced flow will eventually reduce the output flow rate and move it towards the set point. From this quantitative description, we see that the flow of signals from one component to the next is such that the flow rate of water through the pipe should return to the set point. In a well-tuned control system, the response of the flow will oscillate around the set point before coming to steady state.

STARTUP PROCEDURE:

- ⇒ Connect the air compressor line to the experimental control trainer. Shut off the air supply valve to the trainer.
- ⇒ Start the air compressor by providing 3-phase electric supply to the compressor.
- ⇒ Fill the water supply tank at the bottom of the trainer full with fresh clean water. Make sure that drain valve is closed.
- ⇒ After pressure of air inside compressor has build up sufficient (around 6 – 7 Kg/cm^2) open the discharge valve of compressor and supply valve to the trainer.
- ⇒ Apply 20 psi (or 1.4 Kg/cm^2) to the E/P Converter by regulating pressure from air filter cum regulator. Lock the regulator by pressing ring of it.
- ⇒ Give supply of 230 V AC (5 Amp) to the trainer by three-pin plug provided. Switch ON power supply switch.
- ⇒ Move the toggle switch towards Flow or Cascade Side and configure the controller in LSP mode by pressing up down key simultaneously for two second that time three horizontal line flickering. Now controller in LSP mode.
- ⇒ Switch on the pump by toggle switch provided with indicating lamp. Make sure that the bypass valve is fully open.

- ⇒ Now adjust the set point of the PID Controller to the 50 % and also make necessary P, I, D Setting as per shown in the manual of PID Controller. Now close the bypass valve slightly.
- ⇒ Make sure that the needle valve of Rotameter is fully open during the whole operation.
- ⇒ In control panel you can have recorder output. 4 – 20 ma to whom you can attach recorder of same input type.
- ⇒ Apply a new set point to the PID controller and read the behavior of the loop. Adjust the bypass valve of the pump according to the set point.
- ⇒ To start the programme and select the different control mode through software.
- ⇒ Choose the Mode of Operation or Control action of interest, apply the disturbance/ change of set point and log the data to the computer and analyse it.

SHUTDOWN PROCEDURE:

- ⇒ First of all close the air supply to the E/P Converter / Control valve by closing the regulator provided.
- ⇒ Now switch off the pump and also fully open the bypass valve provided.
- ⇒ Switch off the PID controller.
- ⇒ Switch off the air compressor and shut off the discharge valve of it. Drain the filled air from the cylinder of compressor by opening the drain coke at the bottom of the compressor, Close the air supply valve to the control trainer.
- ⇒ Adjust the set point of the PID Controller to a lower value.
- ⇒ Fully open the ball valve (drain valve) provided at the bottom of the water tank supply tank to remove any quantity of water from the system.
- ⇒ Shutdown the programme from the computer and disconnect the link between computer and PID.
- ⇒ Switch off the power supply to the trainer.

PRECAUTIONS:

- ⇒ For proper operations read the instructions provided and then follow it step by step.
- ⇒ Do not apply higher pressure to the E/P Converter (greater than 1.4 Kg/cm^2) as it may damage it.
- ⇒ Use fresh and clean water always in the water supply tank.
- ⇒ Remove all water from the tank after experiment is over.
- ⇒ Clean pump regularly.
- ⇒ Do not alter wiring of the instrument
- ⇒ Do not alter or modify the any components of the trainer.
- ⇒ Use standard parts provided by D.K. Scientific Industries.

⇒ If possible put trainer in air conditioned room. The computer should not be farther 5 meter from the trainer.

⇒ Do not put instrument idle for longer time. Run it once in a week.

⇒ Give routine maintenance to it Remove dust periodically from the trainer. Any problem encountered during the use of the set up, first refer the instruction manual. If the problem persists, contact us immediately. We provide support for your specific questions or any up gradation.

ROUTINE MAINTENANCE:

⇒ Replace water in case suspended particles are observed. (It is advised to use clean distilled water to improve the reliability of product. Any suspended particles in water may clog the pump strainer causing no discharge through the pump.)

⇒ Check the working of control panel when not in use.

⇒ Disconnect the electric supply to the control panel when not in use.

⇒ Clean pump strainer in sequence as mentioned below.

- ➢ Remove the pump by lifting the support to the pump from the tank.
- ➢ Gently remove the strainer at the suction of the pump by rotating it anti clockwise.
- ➢ Remove the mesh from the strainer. Clean and wash the mesh thoroughly.
- ➢ Fix the mesh back to location properly.
- ➢ Replace the pump in a tank.

⇒ If the variation in actual Flow and transmitter signal is more than three percent, calibrate level transmitter in sequence as mention below.

- ➢ Open the cover of Flow transmitter.
- ➢ Close the Drain valve fully.
- ➢ Switch on the power supply to the unit and Pass the flow from orifice and tapping of transmitter up to 10 % Flow.
- ➢ Adjust the span range as well as zero range by means of push button.
- ➢ Adjust the transmitter according to flow in Rotameter.
- ➢ Repeat the above procedure for at least two times.
- ➢ Close the transmitter cover.
- ➢ See manual for details.

CLOSED LOOP (AUTO MODE) CONTROL

(Proportional + Integral Control)

AIM : To Study the Closed Loop (Auto Mode) Control (Proportional + Integral Control).

PROCEDURE:

⇒ Start the equipment as mentioned in the startup procedure above.

⇒ Select the Auto option by pressing the **AUTO/MANUAL** button provided on the main screen. The button should indicate **AUTO** when the controller is in Auto Control mode.

⇒ Allow the system to attain the steady state at the initial set point (about 50).

⇒ Choose the Save As option in the File menu and save the file by giving appropriate name.

⇒ Choose the **Proportional + Integral (PI)** Control action from the Menu Button on the main screen.

⇒ Click on to the **PID** button and enter the desired value of proportional band and reset time in the popped up screen and apply it.

⇒ Allow the system to achieve the steady state and observe the path followed by the process variable to reach the set point. Change the value of proportional band as well as reset time and observe the same.

⇒ Set point change may also be applied by changing the set point (servo problem) using the up/ down arrow provided besides the indicator of set point or directly inserts the value of desired set point in the set point value box by inserting the cursor.

⇒ Shut down the equipment as mentioned in the shutdown procedure above.

⇒ The value of load change / set point change should be approximately 20% of the range to obtain proper response otherwise the controller may track to its set point without any overshoot/ undershoot.

OBSERVATIONS:

Observe that at any value of proportional band & reset time the value of offset is zero; however the time required for the same varies as the value changes.

Observe the effect of load & set point change on the behavior of the system.

Pressure Control Trainer

Description

The pressure control trainer is designed for teaching the basic pressure control principles study in chemical and instrumentation engineering. For ease of understanding, the product is described with its major components.

INTRODUCTION

Pressure loops vary from very tight, fast loops (almost like flow control) to slow averaging loops (almost like level control). An example of a fast pressure loop is the case of a valve throttling the flow of a vapour from a vessel.

THE CONTROL SYSTEM

An air stream entering the tank maintains the pressure of the air at a value P_i. It is desired to maintain (or control) the pressure of the air at P_R by means of the controller. If the measured pressure P_m differs from the desired pressure P_R, the controller senses the difference or error $\varepsilon = P_R - P_m$, and changes the valve position in such a way that the desired liquid height P_R is obtained in the tank.

COMPONENTS OF A CONTROL SYSTEM:

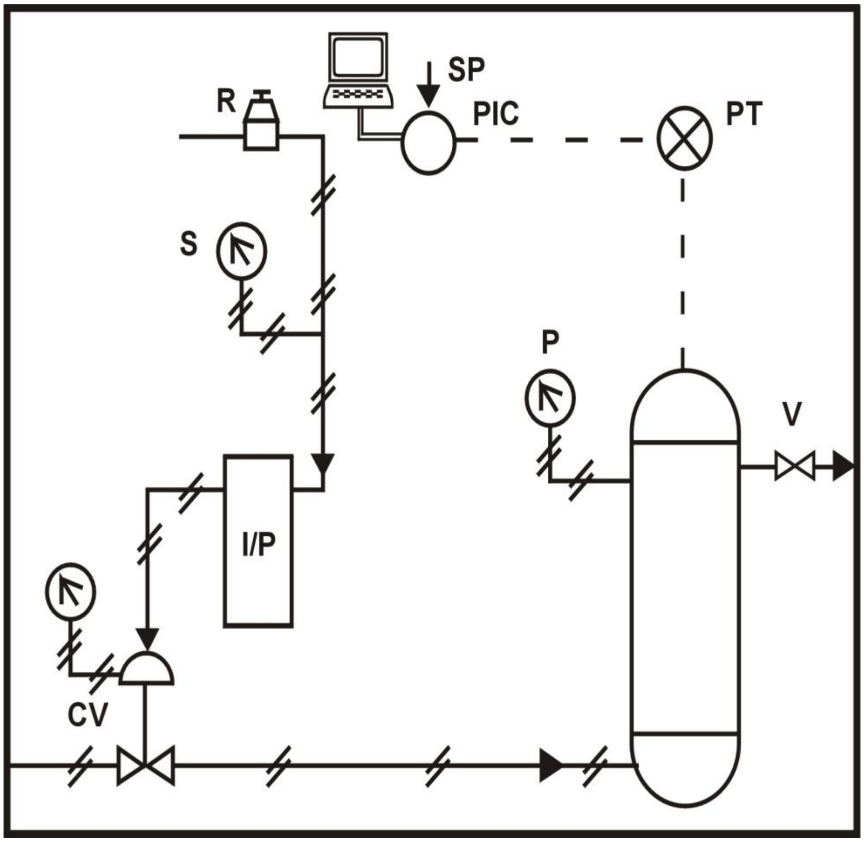


Figure 1. PRESSURE CONTROL TRAINER

The system shown may be divided into the following components:

PT	Pressure Transmitter
I/P	Current to Pneumatic Converter
CV	Pneumatic Control Valve
V	Vent Valve
R	Air Pressure Regulator
S	Supply Pressure Gauge (I/P)
SP	Set Point
PIC	Pressure Indicator Controller

BLOCK DIAGRAM

For computational purposes, it is convenient to represent the control system shown in Figure 1 by means of the block diagram shown in Figure 2. Such a diagram makes it much easier to visualize the relationships among the various signals.

Set Point: : The set point is synonym for the desired value of the controlled variable.

Load: : The load refers to a change in any variable that may cause the controlled variable of the process to change.
In the example, the outlet (vent) valve position is a load variable.

The control system shown in Figure 2 is called a closed loop system or a feed back system because the measured value of the controlled variable is returned to of "fed back" to a device called the comparator. In the comparator, the controlled variable is compared with the desired value or set point. If there is any difference between the measured variable and the set point, an error is generated; this error enters a controller, which in turn adjusts the final control element in order to return the controlled variable to the set point.

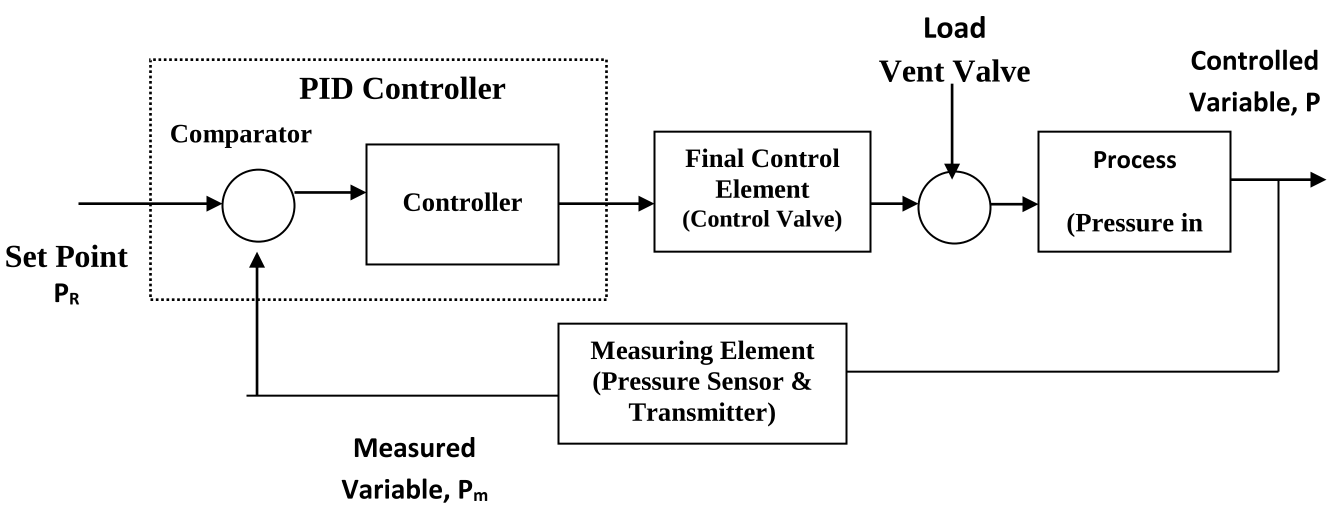


Figure 2. Block Diagram of a Pressure Control System

Functioning of the System

Figure 1 & 2 show that a pressure sensor is used to measure the pressure of air in the tank; the signal from the pressure sensor is sent to the transducer (pressure transmitter), which produces an output in the range of 4-20 mA, which is a linear function of the input. The output of the transducer enters the controller where it is compared to the set point to produce an error signal. The controller converts the error to an output in the range of 4-20 mA according to the control law (P, PI, PD, PID or On-Off) stored in the memory of the controller. The output of the controller enters the I/P converter, which produces an output in the range of 3-15 psig, which is a linear function of the input. Finally, the output of the converter is sent to the top of the control valve, which adjusts the flow of air to the tank. The control valve used here is linear and is pressure-to-open type. The external power of 230 V AC is required for controller and I/P converter and 24 V DC for pressure transmitter. A source of 20-psig airs is needed for the converter.

To see how the components interact with each other, consider the process to be operating at steady state with the outlet flow rate through the tank is equal to the set point. If the outlet flow rate from the tank increases, the following events occur. Immediately the pressure sensor & pressure transmitter detects a decrease in the pressure of the air in the tank and produces a change in the signal to the controller. As soon as the controller detects decrease in the pressure, relative to the set point, the controller output increases according to the control action chosen. The increase in signal to the converter causes the output from the converter to increase and open the valve in order to increase the flow of air. The increased flow will eventually increase the pressure of air in the tank and move it towards the set point. From this quantitative description, we see that the flow of signals from one component to the next is such that the pressure of air in the tank should return to the set point. In a well-tuned control system, the response of the pressure will oscillate around the set point before coming to steady state.

STARTUP PROCEDURE:

⇒ Check that the air pressure regulator supplying air to the control valve (fitted at the back of the equipment) and pressure regulator supplying air to the I/P converter (fitted on the front panel) are shut off properly.

⇒ Check that the drain valve of the air compressor provided beneath the air supply valve of the pressure tank of the air compressor and the air supply valve itself is also shut off.

⇒ Switch ON the air compressor motor and allow the air pressure to build up in the compressor's pressure tank up to about 7-kg/ cm^2 (g).

⇒ Now open the air supply valves provided on the compressor's pressure tank and allow the air to reach the pressure regulators.

⇒ Slowly open the air pressure regulator provided for the pneumatic control valve (fitted at the back of the equipment) and set the pressure near to 1.5 kg/ cm^2 (g) as indicated by the pressure gauge provided on the pressure regulator and pneumatic control valve also.

⇒ Now open the pressure regulator provided for the I/P converter (fitted on the front panel) and set the pressure to 1.4 kg/ cm^2 (g) as indicated by the pressure gauge fitted along with it.

⇒ In control panel you can have recorder output (in the range of 0 – 100 %) (4 – 20 mA) to which you can attach recorder of same input type. (i.e. 4 – 20 mA.) The current meters at the top panels indicate E/P Converter input and Transmitter output in the range of 4 – 20 Ma respectively.

⇒ Check all the air connections for any sort of leakage and in case any leakage is observed tighten it immediately to prevent the loss of compressed air.

⇒ Open the disturbance valve (needle valve) provided on the pressure tank slightly/ to the desired degree.

⇒ Now switch on the PID controller.

⇒ Switch ON the computer and start the software for Pressure Control Trainer by executing the respective executable file (pressure.exe).

⇒ Open the Citect explorer and run the program and select the pressure control trainer.

⇒ Choose the Mode of Operation or Control action of interest, apply the disturbance/ change of set point and log the data to the computer and analyze it.

SHUTDOWN PROCEDURE:

⇒ First of all shutting down the system after experiment, Shutdown the programme.

⇒ Close the air supply to the E/P Converter /control valve by closing the regulator provided.

⇒ Switch off the air compressor and shut off the discharge valve of it. Drain the filled air from the cylinder of compressor by opening the drain coke at the bottom of the compressor. Close the air supply valve to the control trainer.

⇒ Adjust the set point of the PID Controller to a lower value. Switch off the power supply to the trainer.

⇒ Fully open the needle valve (vent valve) provided on the top of the pressure vessel to remove any air quantity of air from the system.

⇒ Switch off the power supply to the trainer.

PRECAUTIONS:

⇒ For proper operation read the instruction provided and then follow it step by step.

⇒ Do not apply very high set point to the PID controller (not above range) as it may damage it may damage the pressure vessel/transmitter after long time through the vessel is tested to the high pressure.

⇒ Do not apply higher pressure to E/P Converter (Greater than 1.4 Kg/cm^2) as it may damage it. Also the lesser pressure (less than 1.4 Kg/cm^2) may not give accurate functioning of it.

⇒ Do not change link position of the control panel terminals.

⇒ Do not alter the wiring of instrument.

⇒ Do not alter or modify the components of the trainer.

⇒ Use standard parts provided by D. K. Scientific Industries.

⇒ Carefully read the manuals of each component fitted in the trainer and understand the product working. Refer the individual manual of each proper maintenance and precautions.
⇒ If possible put trainer in Air-conditioned room.
⇒ Do not put instrument idle for a longer time. Run it once in a week.
⇒ Give routine maintenance to it.
⇒ Remove dust periodically from the trainer.
⇒ Any problem encountered during the use of the set up, first refer instruction manual. If problem persists, contact us immediately. We provide support for your specific questions or any up gradation.

ROUTINE MAINTENANCE:

⇒ Check the working of control panel when not in use.
⇒ Disconnect the electric supply to the control panel when not in use.
⇒ Drain the water content in the air filter regulator regularly.
⇒ Do not allow the pressure in the pressure tank to cross the pressure of 10 Kg/cm2 (Max. limit of pressure tank) as it may damage the pressure sensor transmitter/pressure tank.

CLOSED LOOP (AUTO MODE) CONTROL

(Proportional + Derivative Control)

AIM : To Study the Closed Loop (Auto Mode) Control (Proportional + Derivative Control).

PROCEDURE:

- ⇒ Start the equipment as mentioned in the startup procedure above.
- ⇒ Adjust the opening (approx. 20 %) of the disturbance valve provided on the pressure tank and do not alter it throughout the course of the experiment.
- ⇒ Select the Auto option by pressing the **AUTO/MANUAL** button provided on the main screen. The button should indicate **AUTO** when the controller is in Auto Control mode.
- ⇒ Allow the system to attain the steady state at the initial set point (about 2 kg/ cm^2 (g)) value of pressure in the pressure tank.
- ⇒ Choose the Save As option in the File menu and save the file by giving appropriate name.
- ⇒ Choose the **Proportional + Derivative (PD)** Control action from the Menu/ Radio Button on the main screen.
- ⇒ Click on to the **PID** button and enter the desired value of proportional band and rate time in the popped up screen and apply it.
- ⇒ Allow the system to achieve the steady state and observe the path followed by the process variable to reach the set point. Change the value of proportional band as well as rate time and observe the same.
- ⇒ Load change (regulatory problem) may also be applied by changing the opening position of the disturbance valve provided on the pressure tank. / Set point change may also be applied by changing the set point (servo problem) using the up/ down arrow provided besides the indicator of set point or directly insert the value of desired set point in the set point value box by inserting the cursor.
- ⇒ Shut down the equipment as mentioned in the shutdown procedure above.
- ⇒ The value of load change / set point change should be approximately 20% of the range to obtain proper response otherwise the controller may track to its set point without any overshoot/ undershoot.
- ⇒ While conducting this experiment the process variable value should not exceed the value of 5-kg/ cm^2 (g) as it may damage the pressure tank/ pressure sensor-transmitter.

OBSERVATIONS:

Observe that at any value of proportional & rate time the process variable is not able to reach the set point value.

Observe the effect of load & set point change on the behavior of the system.